Supporting Information

For

Estimating Particulate Exposure from Modern Municipal Waste Incinerators in Great Britain

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ADMS-Urban	Atmospheric Dispersion Modelling System-Urban
AQMS	Air Quality Monitoring Sites
As	Arsenic
AT	Air Temperature
AURN	Automatic Urban and Rural Network
BADC	British Atmospheric Data Centre
CC	Cloud Cover
Cd	Cadmium
Co	Cobalt
Cr	Chromium
Cu	Copper
DTM	Digital Terrain Model
EU-WID	The Waste Incineration Directive (2000/76/EC)
Hg	Mercury
LAQN	London Air Quality Network

Mn	Mangenese
MO	Monin-Obukhov
MWI	Municipal Waste Incinerator
Ni	Nickel
NOx	Nitrogen Oxides
PAH	Polycyclic Aromatic Hydrocarbons
Pb	Lead
PCB	Polychlorinated biphenyls (PCBs)
PCDD/F	Dioxins and Furans
PM_{10}	Particulate matter with diameter <10 µm
RMA	Reduced Major Axis
Sb	Antimony
SELCHP	South East London Combined Heat and Power
SR	Surface Roughness
TEOM	Tapered Element Oscillating Microbalance
Tl	Thallium
V	Vanadium
WD	Wind Direction
WS	Wind Speed

A – Municipal Waste Incinerator (MWI) characteristics

Table S 1 MWI characteristics

MWI	Stack height (m)	Stack diameter (m)	Flue	Exit temperature (°C)	Exit velocity (m s^{-1})
Allington	80	1.70	1	165.00	31.00
			2	173.00	30.00
			3	164.00	29.00
Bolton	60	1.70	1	139.00	17.10
Chineham	65	1.22	1	147.60	20.82
Coventry	92	1.45	1	132.00	17.00
			2	143.00	19.00
			3	135.00	21.00
Crymlyn Burrows	40	0.95	1	136.00	18.20
Dudley	47	1.04	1	170.00	18.20
			2	170.00	16.00
Dundee	69	1.10	1	134.00	20.00
			2	138.00	20.20
Eastcroft	91	1.32	1	132.00	23.20
			2	131.00	24.30

MWI	Stack height (m)	Stack diameter (m)	Flue	Exit temperature (°C)	Exit velocity (m s^{-1})
Edmonton	100	2.87	1	159.00	11.20
			2	150.00	11.10
Grundon (Lakeside)	75	2.08	1	69.00	20.30
			2	65.50	19.30
Isle of Wight	26	1.00	1	130.00	12.40
Kirklees	93	1.77	1	144.00	19.30
Marchwood	65	1.25	1	149.85	24.70
			2	147.85	25.20
Newlincs (Grimsby)	42	1.19	1	133.00	18.10
Porthmellon	23	0.76	1	163.00	16.80
Portsmouth	65	1.25	1	125.00	18.00
			2	125.00	18.00
SELCHP*	100	2.40	1	150.00	25.50
			2	149.00	19.10
Sheffield	76	1.45	1	146.00	13.00
			2	147.00	12.00

MWI	Stack height (m)	Stack diameter (m)	Flue	Exit temperature (°C)	Exit velocity (m s^{-1})
Stockton-on-Tees	70	1.65	1	140.00	19.20
			2	147.00	18.20
			3	147.00	18.10
Stoke-on-Trent	80	1.44	1	135.00	19.10
			2	141.00	20.00
Tyseley	80	2.04	1	132.00	17.58
			2	133.00	17.71
Wolverhampton	76	1.04	1	144.60	23.10
			2	144.40	23.20

*South East London Combined Heat and Power

B – Non-numeric and negative PM_{10} emissions value coding

Table S 2. Non-numeric and negative PM_{10} emissions value coding. Records provided were coded according to these criteria before imputation in the dispersion model.

PM_{10} value reported	NOx record	Comments included	Operational?	Coded as
0	Value>0 reported	-	ON	0
		"Statutory checking of steam pressure system relief vales. Boiler 2 down for repairs to the grate surface" (Sheffield)"	OFF	OFF
	Zero	-	OFF	OFF
		"process not operating"	OFF	OFF
	Zero (but value SOx >0)	-	ON	0
	-	-	ON	0
		"no measurement data in cells marked as – "	ON	0
	n\a	-	OFF	OFF
	Blank	-	ON	0
	blank (but value SOx >0)	-	ON	0
	NR	-	ON	0

PM_{10} value reported	**NOx record**	**Comments included**	**Operational?**	**Coded as**
LOD	LoD	-	ON	PM_{10} value imputed as the lowest value provided for that year
"<1"	Value>0 reported	-	ON	1
	"<1"	-	ON	1
OFF	OFF	-	OFF	OFF
	Blank	"process not operating" / "plant shutdown"	OFF	OFF
N/A	Value>0 reported	-	OFF	OFF
	0	-	OFF	OFF
	NR	-	OFF	OFF
	n/a	-	OFF	OFF
		"not operating"	OFF	OFF
		NO PARTICULATES A2 FOR APRIL	OFF	OFF
	-	-	OFF	OFF
		"no measurement data in cells marked as – "	OFF	OFF
		"A1 not operating"	OFF	OFF
	Blank	-	OFF	OFF
		"only PM10 filled in"	OFF	OFF
		"data is missing"	ON	Missing
NR	NR	-	ON	Missing

PM_{10} value reported	NOx record	Comments included	Operational?	Coded as
Negative values (eg -1,)	Value>0 reported	-	ON	0
	Negative value	-	ON	0
Blank	Value>0 reported	-	ON	Missing
		"no data for particulates"	ON	Missing
	"<1"	"No dust figures for unit 3"	ON	Missing
	n/a	"No form for Particulates for December"	ON	Missing
	Blank, -	-	ON	Missing
		Rest of the records include comments when no PM_{10} data are available	OFF	OFF
		"no data"/ "Missing data"/ "no emission data available" /"no measurement data in cells marked as – "	ON	Missing

PM_{10} value reported	NOx record	Comments included	Operational?	Coded as
Blank		"OFF" / "Process not operating" /"Plant commissioning" /"A1 not operating"	OFF	OFF
	Value reported	Comments when data are not available and coded as -999, therefore originally coded as OFF	OFF	OFF
	-	-	ON	Missing
		"no measurement data"	ON	Missing
-		"not operating"/ "plant shut down where – is recorded"	OFF	OFF
	n/a	"No measurement data for A2"	ON	Missing
*	Value>0 reported	-	ON	Missing
-999	-999	"data unavailable"	ON	Missing
	Value>0 reported	-	ON	Value provided
Emission values >0	Value>0 reported	"No data for Particulates"	ON	Value provided
	Negative value	-	ON	Value provided

PM_{10} value reported	NOx record	Comments included	Operational?	Coded as
Emission values >0	0, -, blank	-	ON	Value provided
		-	ON	Value provided
	-	"no measurement data"/ "no measurement data in cells marked as – "/ "NOX data missing "	ON	Value provided
		-	ON	Value provided
	n/a	"not operating (however PM_{10} shows a reading of 1 on this date)"	ON	Value provided
		-	ON	Value provided
	"<1"	"data is missing"	ON	Missing
	Blank	"data is missing"	ON	Missing

C – Operational, nonoperational and missing days

Table S 3. Number of operational, nonoperational and days of missing data per MWI, per flue, per year

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
Allington	2006	1	39	0	326
		2	38	0	327
		3	42	0	323
	2007	1	94	0	271
		2	93	0	272
		3	115	0	250
	2008	1	107	0	259
		2	123	0	243
		3	83	0	283
	2009	1	281	0	84
		2	252	0	113
		3	279	0	86
	2010	1	247	0	118
		2	234	0	131
		3	247	0	118
Bolton	2003	1	264	62	39
	2004	1	321	0	45
	2005	1	298	31	36
	2006	1	332	0	33
	2007	1	282	0	83

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2008	1	278	30	58
	2009	1	308	0	57
	2010	1	279	36	50
Chineham	2003	1	0	365	0
	2004	1	0	366	0
	2005	1	216	123	23
	2006	1	295	0	70
	2007	1	323	0	42
	2008	1	330	0	36
	2009	1	333	0	32
	2010	1	333	7	25
Coventry	2003	1	0	365	0
		2	0	365	0
		3	0	365	0
	2004	1	366	0	0
		2	366	0	0
		3	335	31	0
	2005	1	29	334	2
		2	25	334	6
		3	20	334	11
	2006	1	308	0	57
		2	294	0	71
		3	313	27	25

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2007	1	291	0	74
		2	319	0	46
		3	315	0	50
	2008	1	321	31	14
		2	271	31	64
		3	311	31	24
	2009	1	277	31	57
		2	317	31	17
		3	310	31	24
	2010	1	267	92	6
		2	245	92	28
		3	254	92	19
Crymlyn	2003	1	34	31	300
Burrows	2004	1	0	0	366
	2005	1	166	32	167
	2006	1	204	0	161
	2007	1	264	0	101
	2008	1	227	0	139
	2009	1	225	0	140
	2010	1	188	0	177
Dudley	2003	1	0	365	0
		2	0	365	0

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2004	1	0	366	0
		2	0	366	0
	2005	1	0	365	0
		2	0	365	0
	2006	1	311	31	23
		2	323	31	11
	2007	1	347	0	18
		2	323	26	16
	2008	1	296	61	9
		2	300	61	5
	2009	1	252	92	21
		2	257	92	16
	2010	1	349	0	16
		2	346	0	19
Dundee	2005	1	85	0	280
		2	0	0	365
	2006	1	281	1	83
		2	179	0	186
	2007	1	281	0	84
		2	309	7	49
	2008	1	268	0	98
		2	223	70	73

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2009	1	298	0	67
		2	246	35	84
	2010	1	268	7	90
		2	169	173	23
Eastcroft	2003	1	332	1	32
		2	319	0	46
	2004	1	326	0	40
		2	310	0	56
	2005	1	136	92	137
		2	188	92	85
	2006	1	303	0	62
		2	263	0	102
	2007	1	264	0	101
		2	278	6	81
	2008	1	258	36	72
		2	289	9	68
	2009	1	208	0	157
		2	215	0	150
	2010	1	309	0	56
		2	302	0	63
Edmonton	2003	1	335	30	0
		2	365	0	0

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2004	1	336	30	0
		2	355	11	0
	2005	1	337	0	28
		2	331	3	31
	2006	1	365	0	0
		2	365	0	0
	2007	1	364	0	1
		2	364	0	1
	2008	1	333	31	2
		2	364	0	2
	2009	1	364	1	0
		2	365	0	0
	2010	1	365	0	0
		2	354	0	11
Grundon (Lakeside)	2010	1	311	0	54
		2	307	0	58
Isle of Wight	2009	1	61	0	304
	2010	1	125	0	240
Kirklees	2003	1	0	365	0
	2004	1	0	366	0
	2005	1	0	365	0
	2006	1	292	66	7
	2007	1	307	31	27

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2008	1	219	3	144
	2009	1	316	48	1
	2010	1	339	17	9
Marchwood	2004	1	244	0	121
		2	240	0	125
	2005	1	310	0	55
		2	303	0	62
	2006	1	325	0	40
		2	327	0	38
	2007	1	340	0	26
		2	328	0	38
	2008	1	341	0	24
		2	330	2	33
	2009	1	329	0	36
		2	342	0	23
	2010	1	61	0	305
		2	54	0	312
Newlincs	2004	1	322	0	43
(Grimsby)	2005	1	307	31	27
	2006	1	330	11	24
	2007	1	307	31	28
	2008	1	304	31	30
	2009	1	292	30	43

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2010	1	265	35	66
Porthmellon	2003	1	228	91	46
	2004	1	161	88	117
	2005	1	171	106	88
	2006	1	90	182	93
	2007	1	206	0	159
	2008	1	207	0	159
	2009	1	157	0	208
	2010	1	197	0	168
Portsmouth	2005	1	60	0	132
		2	62	0	134
	2006	1	63	0	58
		2	90	0	60
	2007	1	99	0	49
		2	308	0	48
	2008	1	50	0	26
		2	210	0	22
	2009	1	346	0	19
		2	343	0	22
	2010	1	341	0	24
		2	344	0	21
SELCHP*	2003	1	276	0	89
		2	245	0	120

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2004	1	335	31	0
		2	335	31	0
	2005	1	362	0	3
		2	360	0	5
	2006	1	342	0	23
		2	295	30	40
	2007	1	324	0	41
		2	327	0	38
	2008	1	329	0	37
		2	331	0	35
	2009	1	303	0	62
		2	329	0	36
	2010	1	340	0	25
		2	312	1	52
Sheffield	2003	1	301	0	64
		2	280	0	85
	2004	1	319	0	47
		2	331	0	35
	2005	1	285	0	80
		2	289	0	76
	2006	1	340	0	25
		2	0	0	365

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2007	1	313	0	52
		2	0	0	365
	2008	1	292	0	74
		2	0	0	366
	2009	1	337	0	28
		2	0	0	365
	2010	1	325	1	39
		2	0	0	365
Stockton-on-Tees	2003	1	308	51	6
		2	326	35	4
		3	0	0	365
	2004	1	327	39	0
		2	315	51	0
		3	0	0	365
	2005	1	323	42	0
		2	326	31	8
		3	0	0	365
	2006	1	314	4	47
		2	314	1	50
		3	0	0	365
	2007	1	305	0	60
		2	321	1	43
		3	0	0	365

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2008	1	286	2	78
		2	312	0	54
		3	0	0	366
	2009	1	228	2	135
		2	263	3	99
		3	177	10	178
	2010	1	248	1	116
		2	271	0	94
		3	296	0	69
Stoke-on-Trent	2003	1	259	90	16
		2	244	90	31
	2004	1	321	0	45
		2	343	0	23
	2005	1	15	334	16
		2	15	334	16
	2006	1	289	0	76
		2	291	0	74
	2007	1	312	31	22
		2	310	31	24
	2008	1	334	0	32
		2	321	0	45
	2009	1	337	0	28
		2	334	0	31

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2010	1	276	0	89
		2	285	0	80
Tyseley	2003	1	61	31	273
		2	62	30	273
	2004	1	366	0	0
		2	366	0	0
	2005	1	334	31	0
		2	334	31	0
	2006	1	336	2	27
		2	324	0	41
	2007	1	337	0	28
		2	340	0	25
	2008	1	348	0	18
		2	347	0	19
	2009	1	343	0	22
		2	339	0	26
	2010	1	287	61	17
		2	280	61	24
Wolverhampton	2003	1	341	0	24
		2	326	31	8
	2004	1	334	0	32
		2	299	29	38

MWI	Year	Flue	No. of operational days	No. of days of missing data	No. of non-operational days
	2005	1	90	274	1
		2	89	274	2
	2006	1	347	0	18
		2	312	31	22
	2007	1	353	0	12
		2	325	28	12
	2008	1	295	61	10
		2	268	91	7
	2009	1	350	0	15
		2	345	0	20
	2010	1	295	62	8
		2	293	62	10

*South East London Combined Heat and Power

D – Sensitivity analysis: Missing data imputation

The imputation of missing data was necessary when the Municipal Waste Incinerator (MWI) was operational but no emission data was recorded. There was wide variability in periods with missing records, from 1-2 days to 3-10 months. Several imputation methods were tested using a year of data from two MWIs, chosen for their variety in missing data periods:

1. Kirklees. In 2007 Kirklees had 31 missing days of data. The missing days are distributed throughout the year, with a maximum continuous period of 9 days of missing data.
2. Dudley. In 2009 Dudley had 92 days of missing data. The missing data was concentrated over a single 3 month period (October-December).

Several missing day imputation methods were conducted and compared:

a) The annual mean of the operational days (per year and per flue), now referred to as 'mean'
b) The annual median of the operational days (per year and per flue) now referred to as 'median'
c) The maximum value of the operational days (per year and per flue) now referred to as 'maximum'
d) The mean average of the day immediately before and the day immediately after the missing period, now referred to as 'day average'

The imputation methods were implemented for the MWIs above using Atmospheric Dispersion Modelling System-Urban (ADMS-Urban). Daily modelled PM_{10} concentrations were calculated at each postcode within 10km of the MWIs. The daily modelled PM_{10} concentrations were aggregated into rolling three monthly averages to estimate trimester specific exposures (which will be used in an epidemiological study investigating reproductive and infant health outcomes around MWIs). Figure S 1 shows the effect of the different imputation methods for the MWIs.

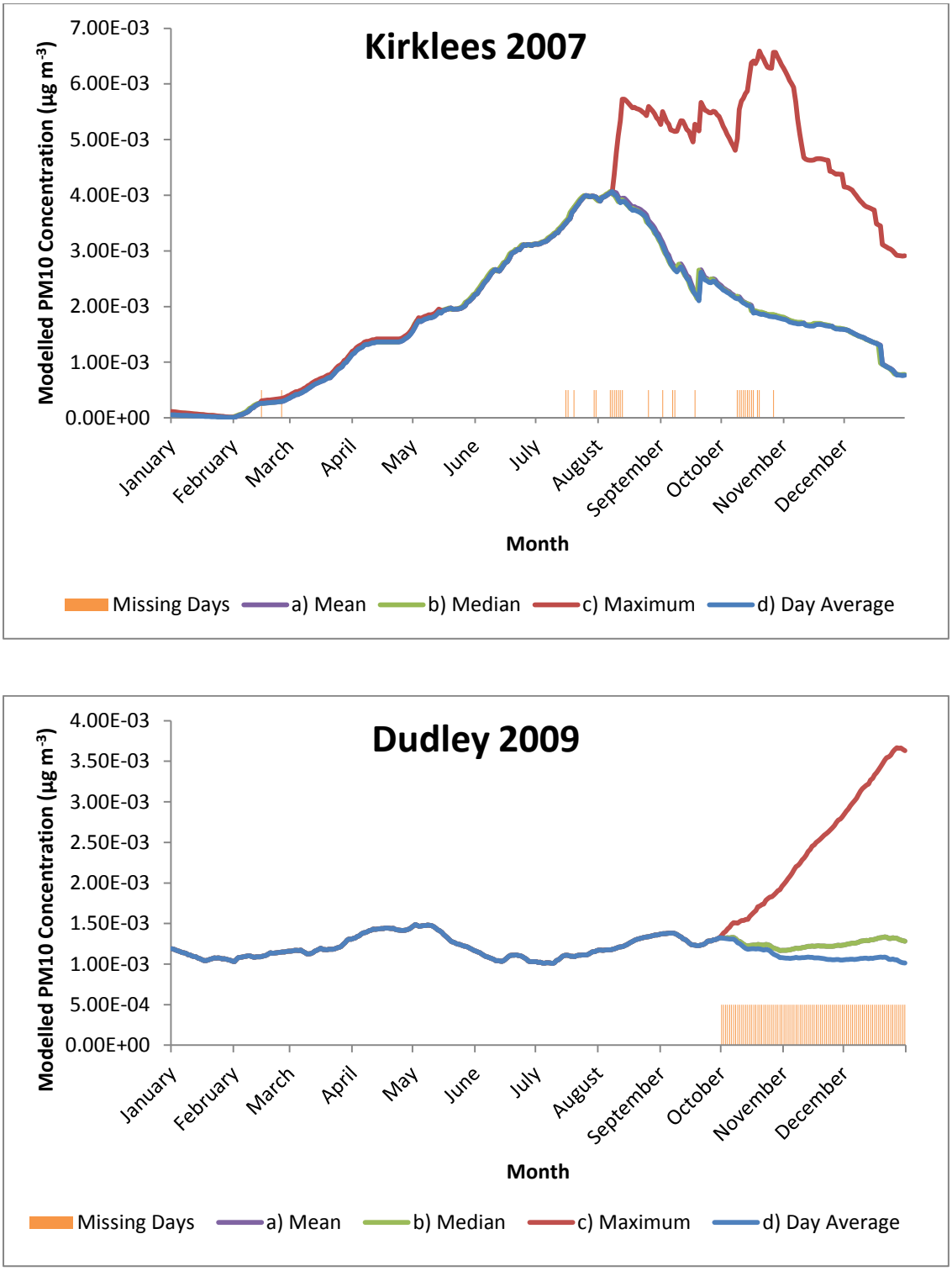


Figure S 1. Daily average modelled PM_{10} concentrations (across all postcodes) when imputing the different missing day methods for Kirklees 2007 (top) and Dudley 2009 (bottom).

Figure S 1 shows that the mean and median methods provided similar outputs, and were less affected by extreme values. Using maximum data results provide more extreme values compared to the other imputation methods, particularly when there are large periods of missing data. The day average, the outputs were

similar to the mean and median for short periods of missing data, however there were differences for longer periods of missing data. Overall the mean or median approaches appear to provide a more stable estimate of the missing data. As there are occasionally extreme emission values affecting the mean, the median was considered to be more representative of the missing days.

A complete year of data with days randomly removed was used to validate the missing days imputation method. Data for 2007 from Edmonton MWI was used. Two scenarios were tested:

1. Shorter periods of data, in clusters of no more than 5 days, were removed. 34 days of data were removed in total. Now referred to as 'short'.
2. Longer periods of data, two blocks of 30 days of data were removed. 60 days of data were removed in total. Now referred to as 'long'

Both were compared to the original data, now referred to as 'original'. Modelled output results are compared in Figure S 2.

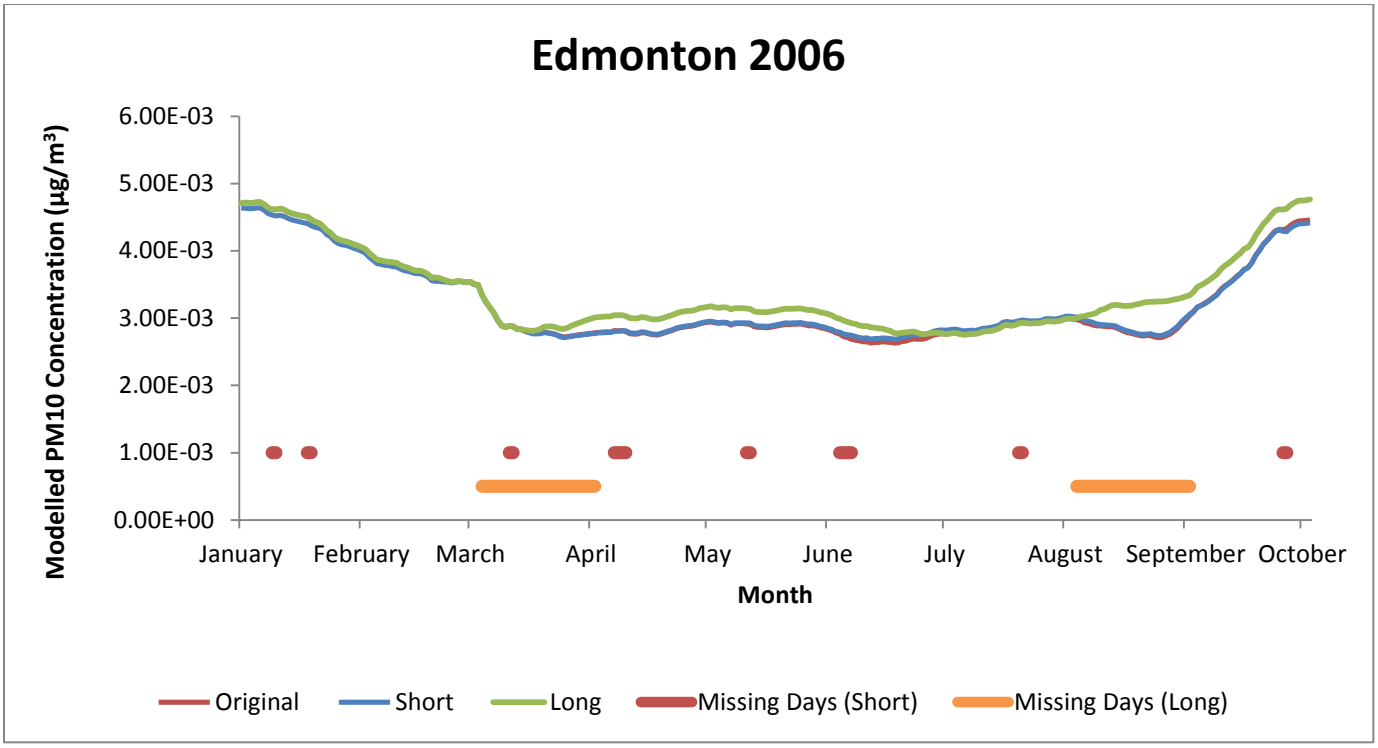


Figure S 2. Daily average modelled PM_{10} concentrations (across all postcodes) when imputing the different missing day methods for Edmonton 2006

Figure S 2 shows that the modelled outputs for the short and long periods of missing days are quite similar to the original data. Therefore the annual median value of the operation days was used to impute missing data.

E – Meteorological data selection

Hourly land surface meteorological observations from all meteorological stations operated by the Met Office in Great Britain between 2003 and 2010 were obtained from the British Atmospheric Data Centre (BADC). Information on the wind direction (WD) and wind speed (WS), cloud cover (CC), and air temperature (AT) was extracted from the BADC data. Candidate meteorological stations located within 30km from each MWI were identified. Only meteorological stations with 90% completeness of WD, WS and AT data were considered, for each year. Some meteorological stations did not measure CC; in these instances CC from the nearest meteorological station was obtained, with a 90% completeness. To ensure that the land type surrounding the meteorological station was representative of the MWI, CORINE land cover (an inventory of land cover, in 44 classes, from the European Environment Agency) and Digital Terrain Model (DTM) (a topographic model of the Earth's surface) data were extracted in a 1km radius of each MWI and meteorological station and compared.

Ideally, data from the meteorological station located nearest to an MWI would be used, however not all meteorological stations within 30km of each MWI had complete data, or was on located on land representative of the MWI. Therefore data from the meteorological station located nearest to the MWI, fulfilling this criteria was selected and used; the selected meteorological stations per MWI and year are provided in Table S 4.

Table S 4. Meteorological stations selected per MWI

MWI	Years	Met Station name (code)	Distance from MWI (m)	Cloud cover from the same Met Station? (details if no)
Allington	2006-2010	EAST MALLING (744)	2,948	No (SHOEBURYNESS: LANDWICK (498), 2006-2010)
Bolton	2003-2010	MANCHESTER: HULME LIBRARY (18904)	15,284	No (RINGWAY (1135), 2003-2010)
Chineham	2005-2010	ODIHAM (862)	9,091	Yes
Coventry	2004-2010	COVENTRY COUNDON (24102)	4,310	No (COLESHILL (19187), 2004-2008; CHURCH LAWFORD (595), 2009-2010)
Crymlyn Burrows	2003-2010	MUMBLES HEAD (1255)	9,612	No (MUMBLES HEAD (1255), 2003-2006; PEMBREY SANDS (1226), 2007-2010)

MWI	Years	Met Station name (code)	Distance from MWI (m)	Cloud cover from the same Met Station? (details if no)
Dudley	2006-2010	ELMDON (593)	23,797	No (COLESHILL (19187), 2006-2010)
Dundee	2005-2009	LEUCHARS (235)	12,320	Yes
	2010	DUNDEE (RIVERSIDE PARK) (18918)	8,091	No (LEUCHARS (235), 2005-2010)
Eastcroft	2003-2010	NOTTINGHAM: WATNALL (556)	10,070	Yes
Edmonton	2003	ENFIELD (717)	2,253	No (LONDON CITY WEATHER CENTRE (19144), 2003)
	2004-2005	LONDON WEATHER CENTRE (19144)	11,620	Yes (2004) No (NORTHOLT (709), 2005)

MWI	Years	Met Station name (code)	Distance from MWI (m)	Cloud cover from the same Met Station? (details if no)
Edmonton	2006-2009	LONDON CITY (18929)	13,338	No (NORTHOLT (709), 2006-2009)
	2010	LONDON: OLYMPIC PARK NORTH (56472)	8,406	No (NORTHOLT (709), 2010)
Grundon (Lakeside)	2010	HEATHROW (708)	3,840	Yes
Isle of Wight	2009-2010	SOLENT (858)	14,365	No (HURN (842), 2009-2010)
Kirklees	2006-2010	BINGLEY: NO 2 (513)	18,156	Yes
Marchwood	2003-2010	SOUTHAMP-TON: OCEANO-GRAPHY CENTRE (25727)	3,305	No (SOLENT (858), 2003-2005; MIDDLE WALLOP (847), 2006-2010)
Newlincs (Grimsby)	2003-2008	DONNA NOOK NO 2 (405)	24,500	Yes (2003-2008)
	2009-2010	HUMBERSIDE (18923)	9,300	No (DONNA NOOK NO. 2 (405), 2009-2010)

MWI	Years	Met Station name (code)	Distance from MWI (m)	Cloud cover from the same Met Station? (details if no)
Porthmellon	2003	SCILLY: ST MARYS AIRPORT (1386)	821	Yes (2003) No (CULDROSE (1393), 2004-2010)
Portsmouth	2005-2006	THORNEY ISLAND (779)	9,440	Yes (2009-2010) No (SOLENT (858), 2005-2006; ODIHAM (862), 2007-2009)
SELCHP*	2003-2004	SOUTHWARK (24946)	2,353	No (LONDON WEATHER CENTRE (19144), 2003-2004)
	2005	LONDON WEATHER CENTRE (19144)	5,974	No (NORTHOLT (709), 2005)
	2006-2009	LONDON CITY (18929)	9,352	No (NORTHOLT (709), 2006-2009)

MWI	Years	Met Station name (code)	Distance from MWI (m)	Cloud cover from the same Met Station? (details if no)
	2010	LONDON: OLYMPIC PARK SOUTH (56471)	5,972	Yes
Sheffield	2003-2005	ROTHERHAM: BRITISH STEEL (18905)	10,222	No (NOTTINGHAM: WATNALL (556), 2003-2005)
	2005-2010	NOTTINGHAM: WATNALL (556)	44,600	Yes
Stockton-on-Tees	2003-2005	MIDDLES-BROUGH: LONGLANDS COLLEGE (25351)	4,057	No (LOFTUS (17344), 2003-2005)
	2006-2009	LOFTUS (17344)	25,901	Yes
	2010	TEES-SIDE (18941)	5,871	No (LOFTUS (17344), 2010)
Stoke-on-Trent	2003-2004	KEELE: UNIVERSITY ROOF (25054)	6,210	No (LEEK: THORNCLIFFE (30690), 2003-2004)

MWI	Years	Met Station name (code)	Distance from MWI (m)	Cloud cover from the same Met Station? (details if no)
	2005-2010	LEEK: THORNCLIFFE (30690)	20,000	Yes
Tyseley	2003-2005	COLESHILL (19187)	10,723	Yes
	2006-2010	ELMDON (593)	7,012	No (COLESHILL (19187), 2006-2010)
Wolverhampton	2003-2005	WOLVERHAMPTON (24948)	1,440	No (COLESHILL (19187), 2003-2005)
	2006-2010	ELMDON (593)	30,592	No (COLESHILL (19187), 2006-2010)

*South East London Combined Heat and Power

F – Monin-Obukhov and Surface Roughness length input values

Table S 5. Monin-Obukhov (MO) and Surface Roughness (SR) length input values imputed into ADMS-Urban informed by CORINE land cover. Methods were informed by work conducted by Ashworth et al.[1]

MWI	MO length (m)	SR length (m) At the dispersion site	SR length (m) At the meteorological site
Allington	10	0.5	0.2
Bolton	10	0.5	0.2
Chineham	10	0.2	0.2
Coventry	10	0.5	0.2
Crymlyn Burrows	10	0.5	0.2
Dudley	10	0.75	0.2
Dundee	10	0.5	0.2
Eastcroft	30	0.5	0.2
Edmonton	100	1.5	1
Grundon (Lakeside)	10	0.5	0.2
Isle of Wight	10	0.5	0.2
Kirklees	10	0.75	0.2
Marchwood	10	0.5	0.2
Newlincs (Grimsby)	10	0.2	0.2
Porthmellon	10	0.2	0.2
Portsmouth	10	0.5	0.2
SELCHP*	100	1.5	1
Sheffield	30	1	0.2

Stockton-on-Tees	10	0.75	0.2
Stoke-on-Trent	10	0.75	0.2
Tyseley	10	0.75	0.2
Wolverhampton	10	0.75	0.2

*South East London Combined Heat and Power

G – Non-continuous measurements

Table S 6 Number of times that the heavy metals (cadmium (Cd), thallium (Tl), mercury (Hg), antimony (Sb), arsenic (As), chromium (Cr), lead (Pb), cobalt (Co), copper (Cu), manganese (Mn), nickel (Ni), and vanadium (V)) and heavy metal compounds (cadmium and thallium (CdTl), mercury compounds (Hg Comp), and groups other heavy metals (OHM)), dioxins and furans (PCDD/Fs), polychlorinated biphenyls (PCBs), Polycyclic Aromatic Hydrocarbons (PAHs) data were measured per pollutant per MWI.

MWI	Cd	Tl	Hg	Sb	As	Cr	Pb	Co	Cu	Mn	Ni	V	CdTl	Hg Comp	OHM	PCDD/F	PAH	PCB
Allington	0	0	0	0	0	0	0	0	0	0	0	0	16	16	16	16	16	16
Bolton	10	9	9	6	7	7	7	5	6	7	7	6	23	21	24	16	7	10
Chineham	1	1	1	1	1	1	0	1	1	1	1	1	12	14	20	11	9	11
Coventry	3	3	3	3	3	3	3	3	3	3	3	3	26	19	41	40	18	33
Crymlyn Burrows	5	5	5	5	5	5	5	5	5	5	5	5	22	23	23	12	10	10
Dudley	6	6	0	6	6	6	0	6	6	6	6	6	19	19	19	17	8	15
Dundee	0	0	0	0	0	0	0	0	0	0	0	0	22	21	22	29	19	16
Eastcroft	0	0	0	0	0	0	0	0	0	0	0	0	50	51	55	55	17	24
Edmonton	0	0	0	0	0	0	0	0	0	0	0	0	22	27	27	12	3	7

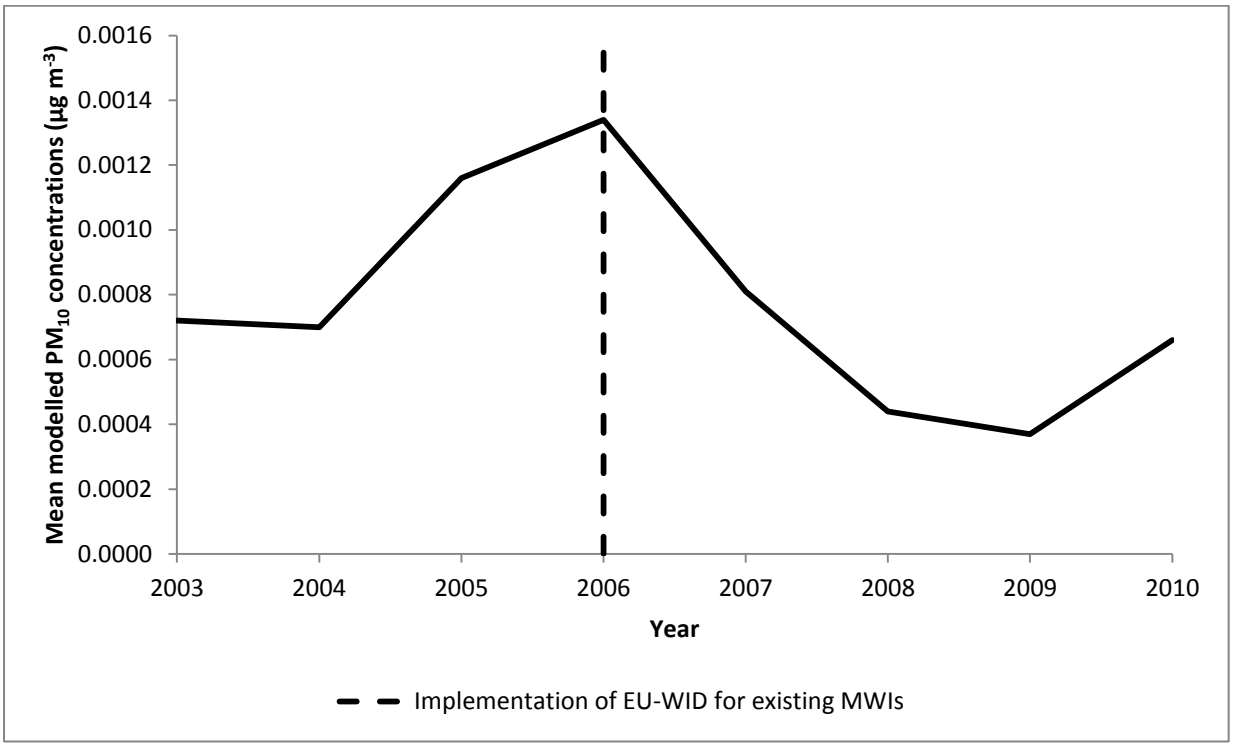
MWI	Cd	Tl	Hg	Sb	As	Cr	Pb	Co	Cu	Mn	Ni	V	CdTl	Hg Comp	OHM	PCDD/F	PAH	PCB
Grundon (Lakeside)	0	0	0	0	0	0	0	0	0	0	0	0	6	6	6	6	1	6
Isle of Wight	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1
Kirklees	0	0	0	0	0	0	0	0	0	0	0	0	6	10	11	11	4	9
Marchwood	0	0	0	0	0	0	0	0	0	0	0	0	31	36	45	30	22	32
Newlincs (Grimsby)	3	3	3	1	1	1	1	0	1	1	1	1	22	22	24	23	19	22
Porthmellon	0	0	0	0	0	0	0	0	0	0	0	0	7	7	7	13	6	6
Portsmouth	0	0	0	0	0	0	0	0	0	0	0	0	22	35	43	29	27	29
SELCHP*	8	8	12	8	8	8	0	8	8	8	7	8	52	47	63	34	20	24
Sheffield	0	0	2	0	0	0	0	0	0	0	0	0	31	33	34	24	12	16
Stockton-on-Tees	1	1	1	1	0	1	0	0	1	1	0	0	50	50	50	47	21	31
Stoke-on-Trent	5	5	5	5	5	5	3	5	5	5	5	5	26	29	31	19	13	19
Tyseley	2	2	2	2	2	2	0	2	2	2	2	2	42	46	46	36	28	31

MWI	Cd	Tl	Hg	Sb	As	Cr	Pb	Co	Cu	Mn	Ni	V	CdTl	Hg Comp	OHM	PCDD/F	PAH	PCB
Wolverhampton	11	10	0	11	11	11	0	11	10	11	11	11	36	41	41	25	13	13
Total	**55**	**53**	**43**	**49**	**49**	**50**	**19**	**46**	**48**	**50**	**48**	**48**	**544**	**574**	**649**	**476**	**594**	**381**

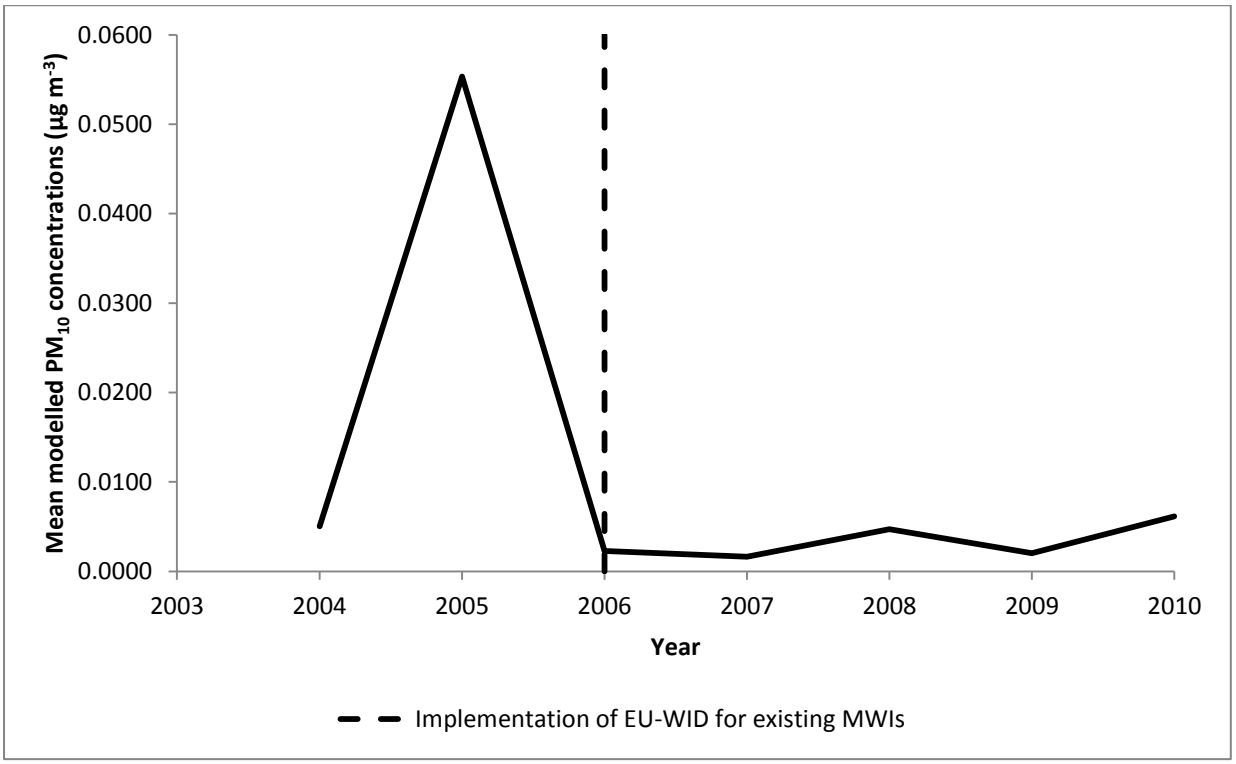
*South East London Combined Heat and Power

H – Mean modelled PM_{10} concentrations (µg m^{-3}) per MWI that adopted EU-WID specifications

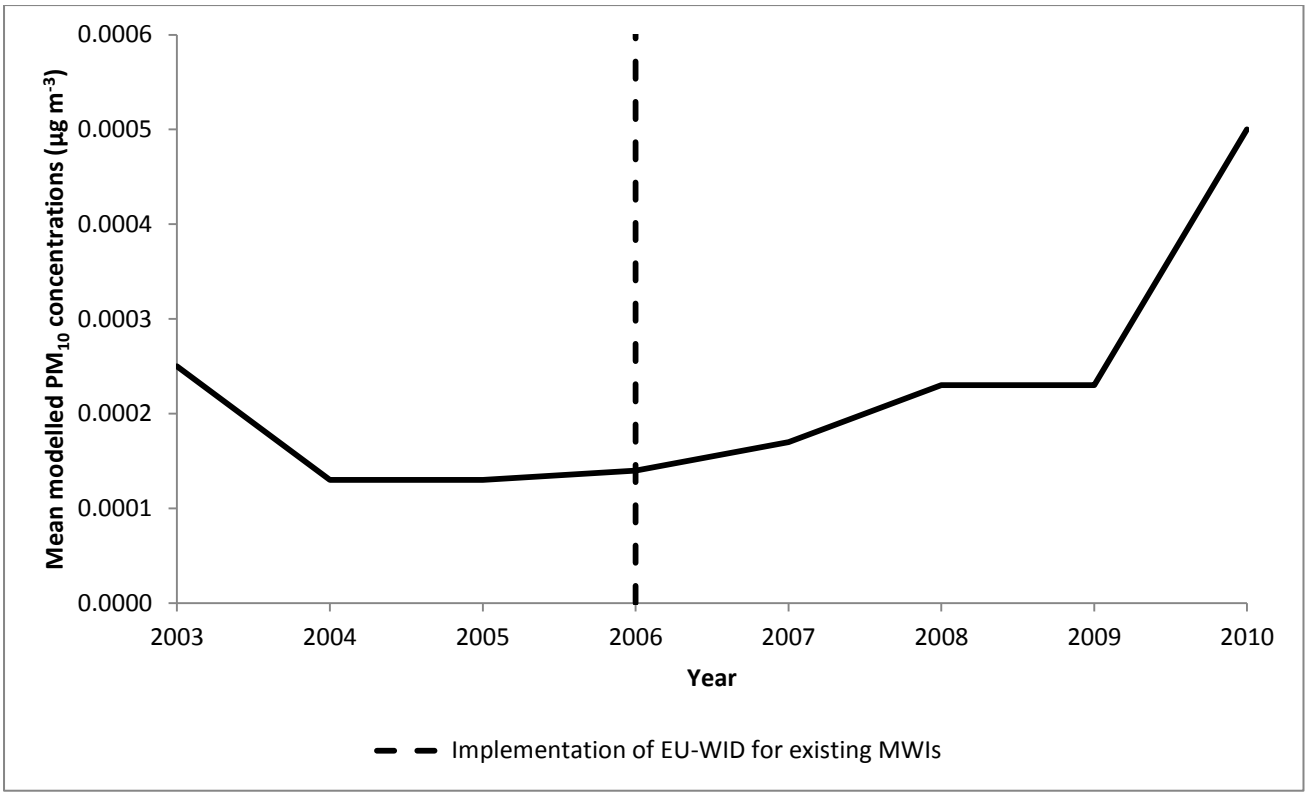
a) Bolton



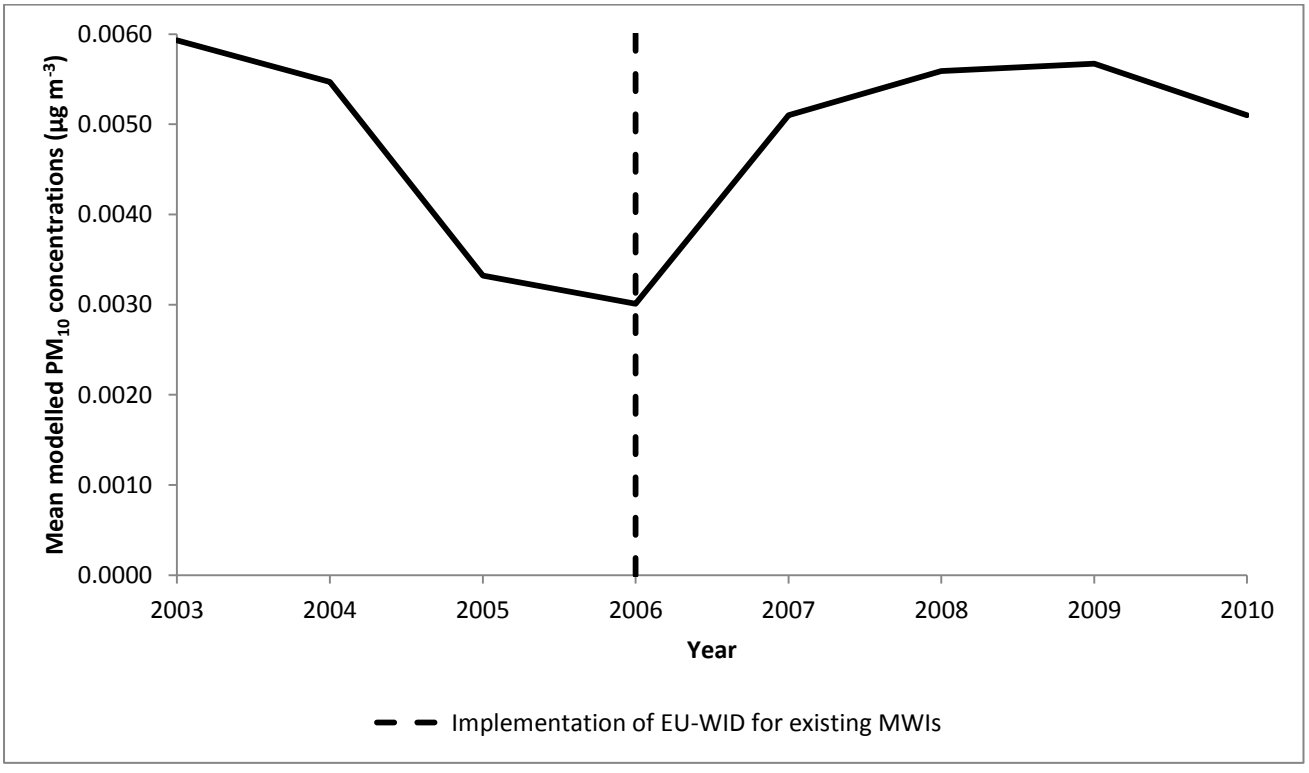
b) Coventry*



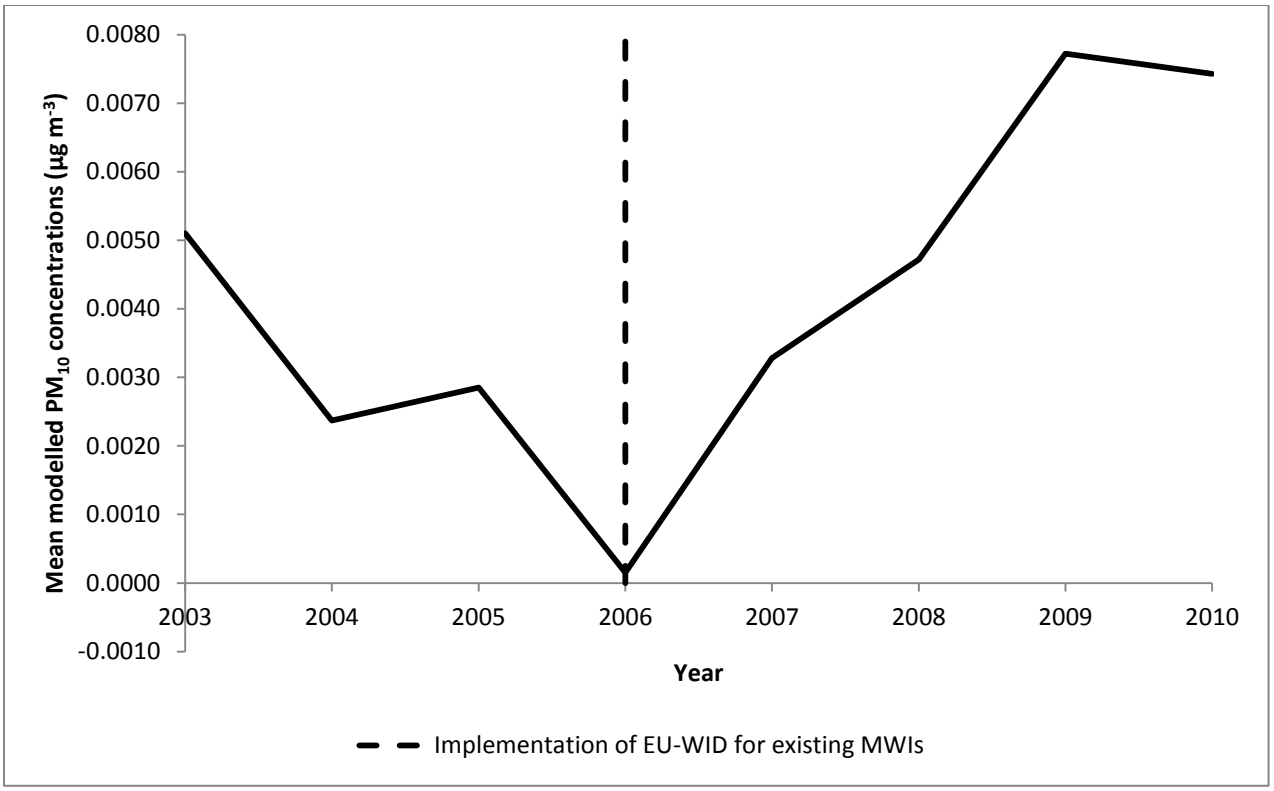
c) Eastcroft



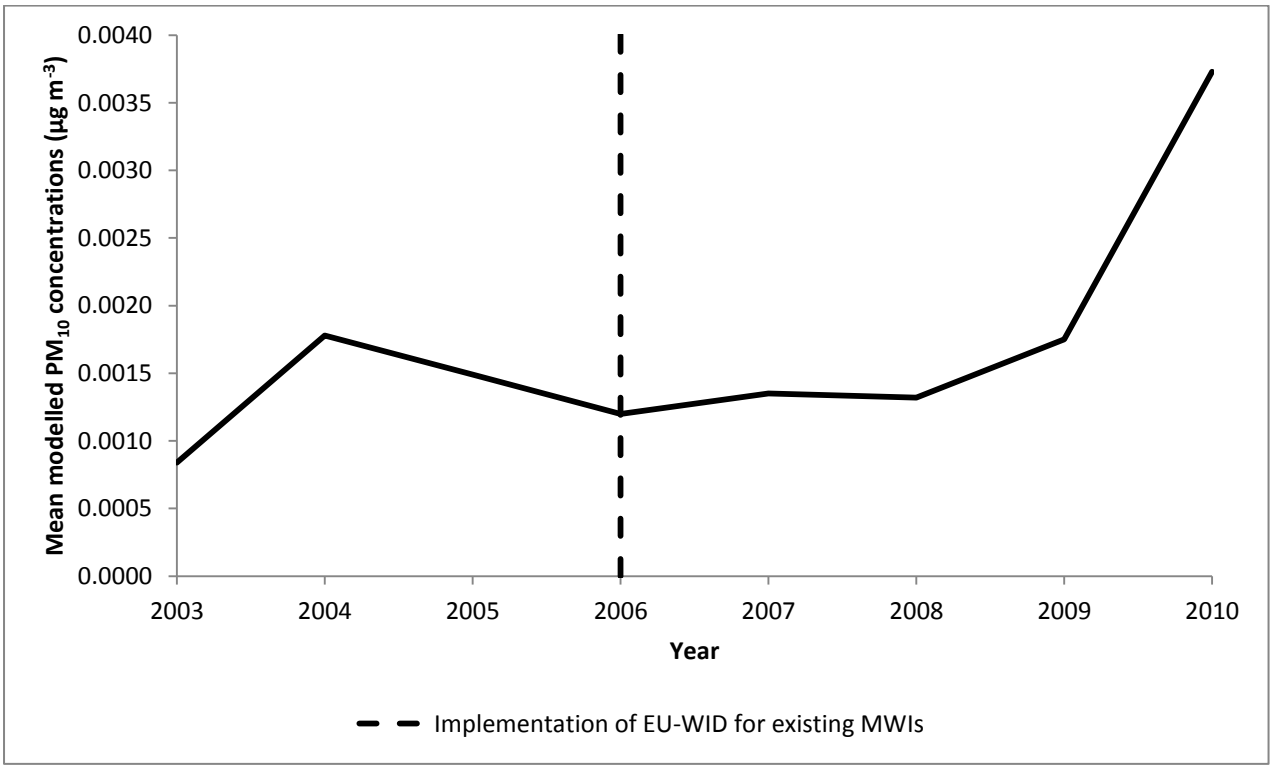
d) Edmonton



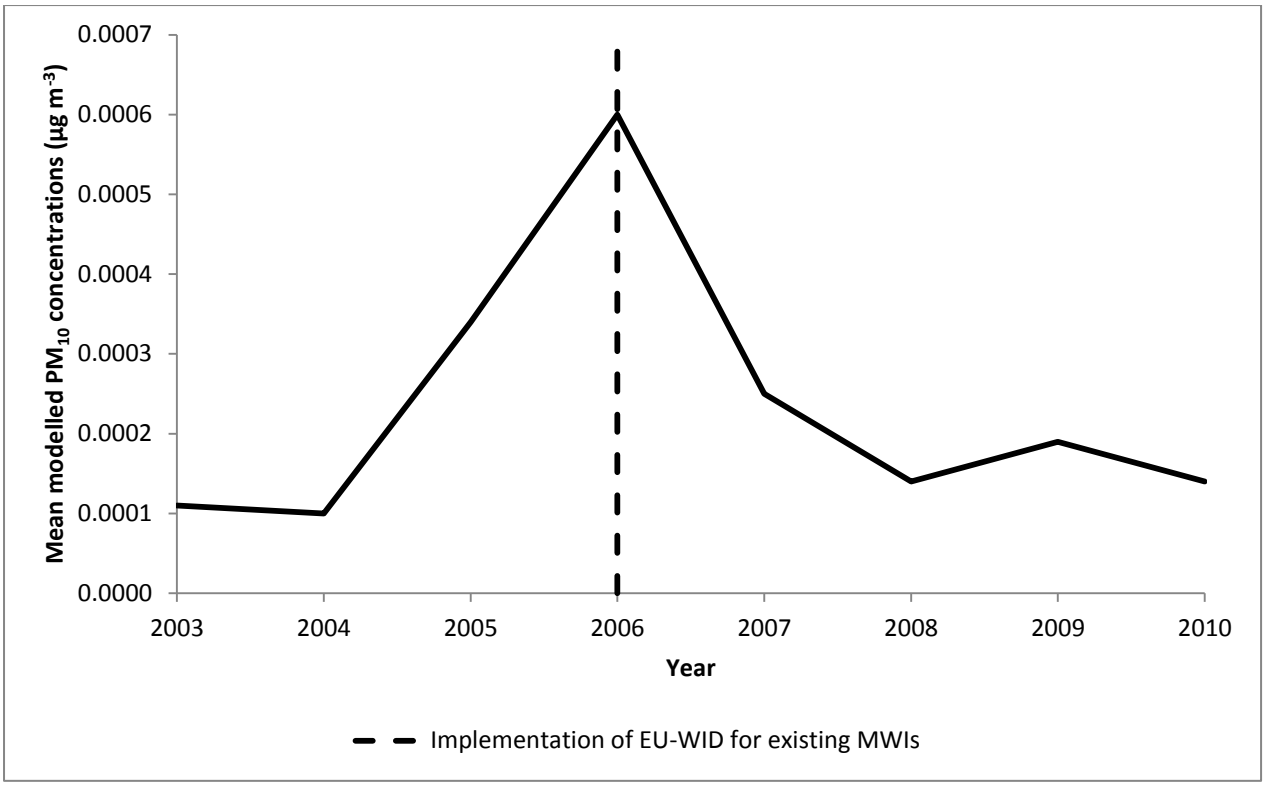
e) Porthmellon



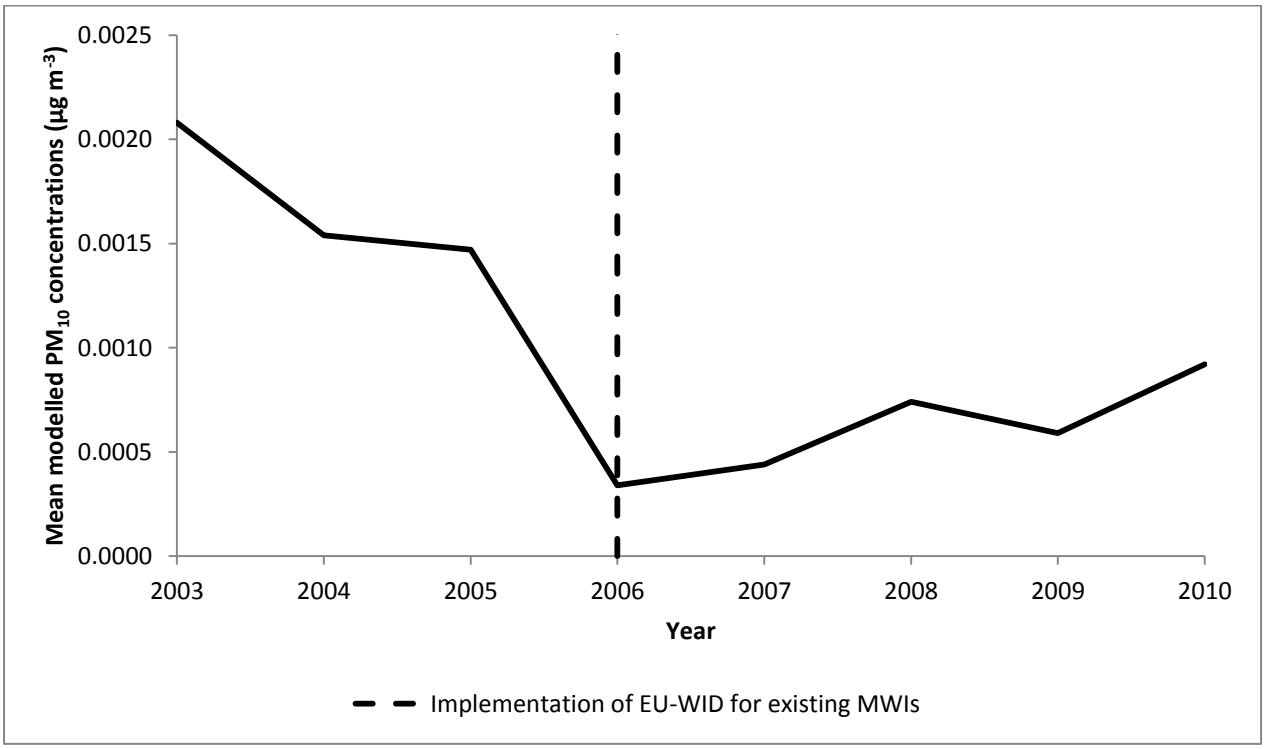
f) SELCHP**



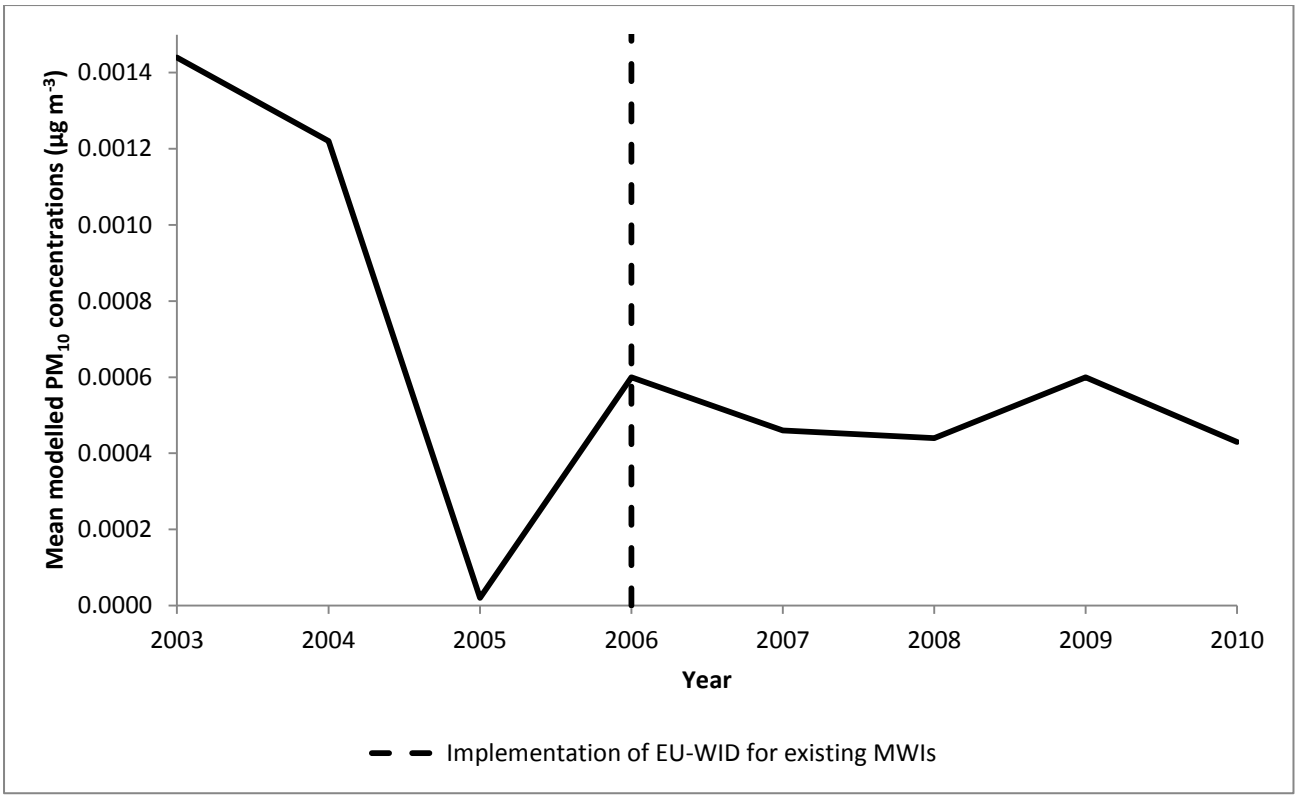
g) Sheffield



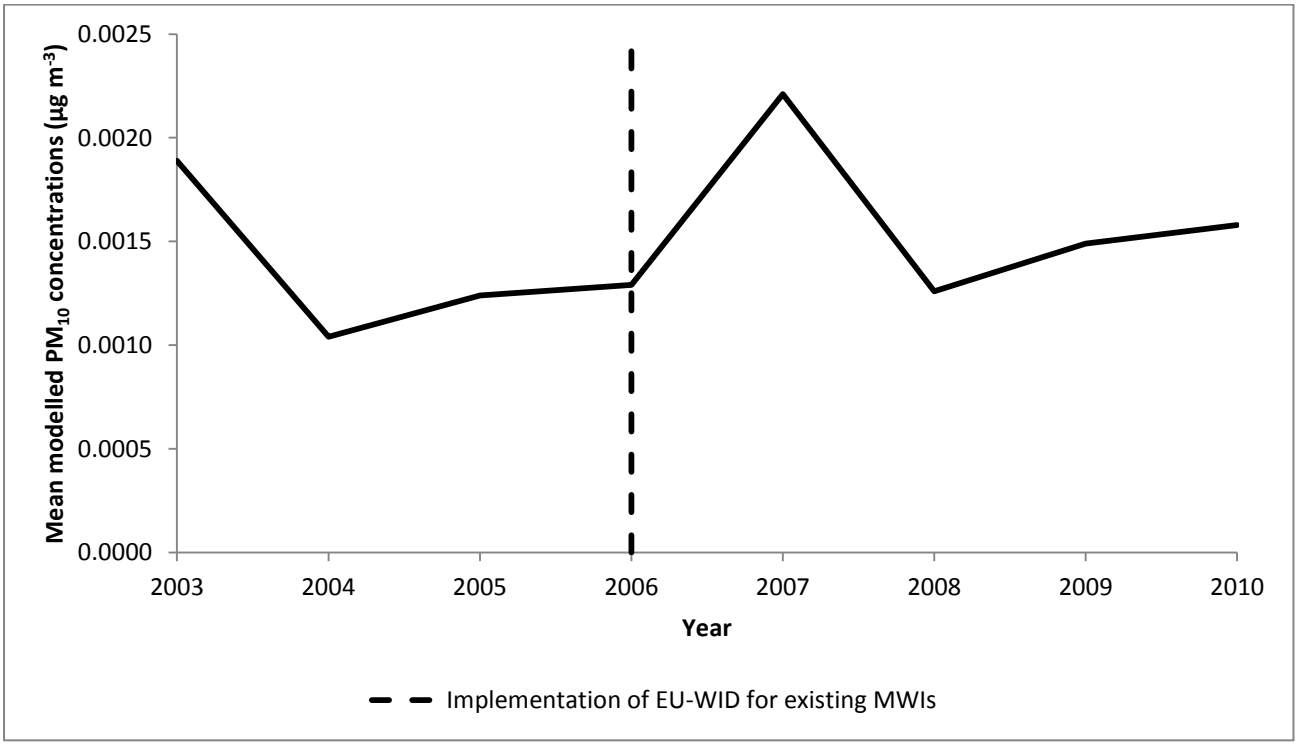
h) Stockton-on-Tees



i) Stoke-on-Trent



j) Tyseley



k) Wolverhampton

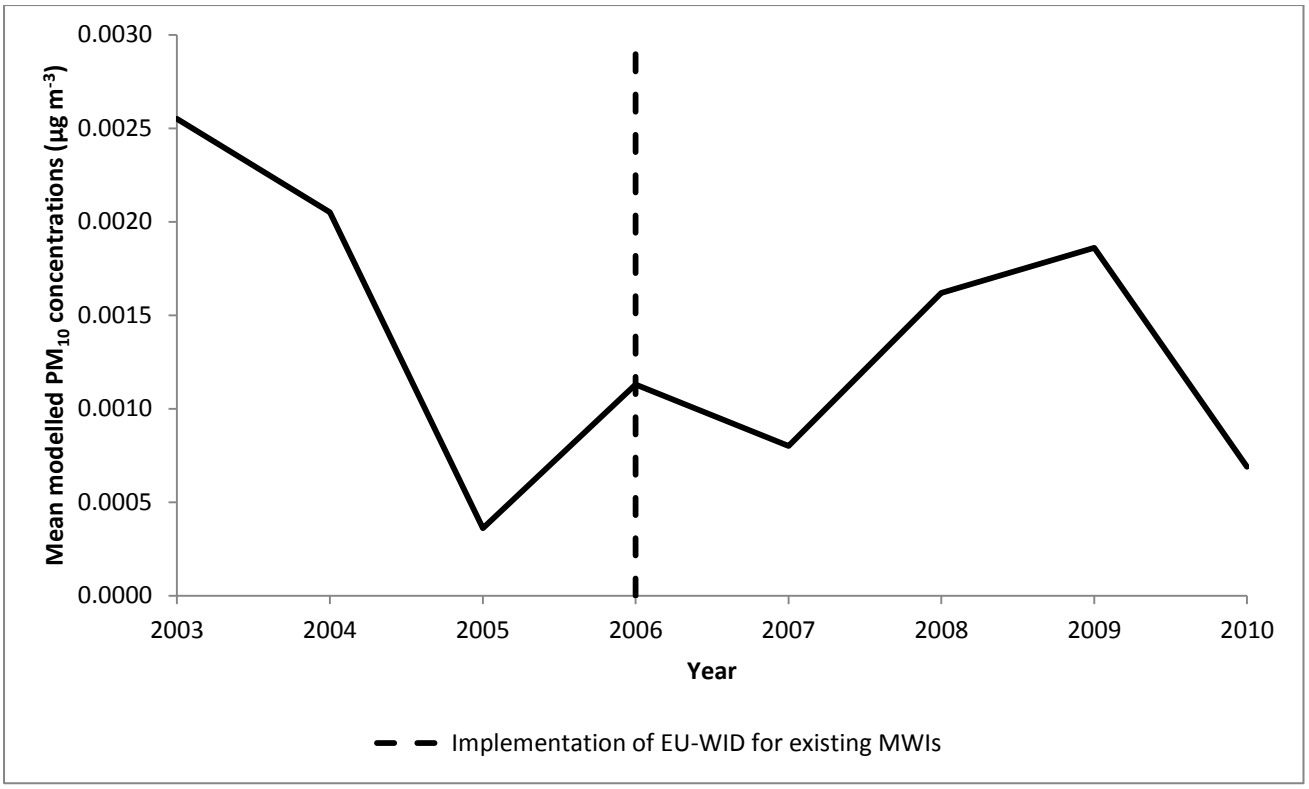


Figure S 3 Mean modelled PM_{10} concentrations per year for a) Bolton, b) Coventry, c) Eastcroft, d) Edmonton, e) Porthmellon, f)SELCHP, g)Sheffield, h) Stockton-on-Tees, i)Stoke-on-Trent, j) Tyseley, and k) Wolverhampton MWIs (the MWIs adopting EU-WID specifications). Dundee MWI was excluded as data were only available from 2005. Dudley MWI and Kirklees MWI was excluded as data were missing for 2003-05. The dotted line represents when the EU-WID was implemented for existing MWIs (28^{th} December 2005).

*It was not possible to model emissions for Coventry MWI in 2003 as data were missing

**SELCHP is an abbreviation of South East London Combined Heat and Power

I – Change point analysis equation

The equation for the Cramér-von Mises test for the change point analysis is provided in Equation S1, with a null hypothesis.

$H_0 : X_i \sim F_0 (x; \theta_0), i = 1, \dots , n$

$$H_0 : X_i \sim \begin{Bmatrix} F_0(x;\theta_0)\ i = 1, \dots, k \\ F_1(x;\theta_1)\ i = k+1, k+2 \dots, n \end{Bmatrix}$$

$$D_n = max_{k=2,\dots,n-1} \left| \frac{D_{k,n} - \mu D_{k,n}}{\sigma D_{k,n}} \right|$$

Equation S 1

Where

n is the number of observations (the daily in-flue PM_{10} measurements)

k is the time point evaluated

F_0 is the distribution before the change point

F_1 is the distribution after the change point

Dn is the maximum of the Cramér-von Mises statistics

μDn is the mean of the Cramér-von Mises statistics

σDn is the standard deviation of the Cramér-von Mises statistics

J – Emissions above the EU-WID daily average particulate limit value

Table S 7 Details of emissions above the EU-WID daily average particulate limit value by year, MWI, and flue (emissions that are not above the EU-WID daily average particulate limit value for a particular MWI, year or flue, are not listed)[1]

MWI	Flue	Year	No. of days PM_{10} emissions were above the EU-WID daily average particulate limit value*					Concentration of highest PM_{10} emission above EU-WID limit* (mg m^{-3})
			>10 - <20	>=20 - <30	>=30 - <40 (mg m^{-3})	>=40 - <50	>50	
Allington	1	2006	10	0	0	0	0	18
		2007	4	0	0	0	0	13
	2	2006	9	9	0	0	0	27
		2007	6	0	0	0	0	13
		2010	11	0	0	0	0	18
	3	2006	26	13	0	0	0	28
		2007	14	1	0	0	0	21
		2010	3	0	0	0	0	18
Bolton	1	2005	5	0	0	0	0	12
		2008	0	1	0	0	0	26
Coventry	1	2007	2	0	0	0	0	14

MWI	Flue	Year	No. of days PM_{10} emissions were above the EU-WID daily average particulate limit value*					Concentration of highest PM_{10} emission above EU-WID limit* ($mg\ m^{-3}$)
			>10 - <20	>=20 - <30	>=30 - <40 ($mg\ m^{-3}$)	>=40 - <50	>50	
	2	2004	3	0	0	0	0	15
		2007	1	0	0	0	0	11
		2008	1	0	0	0	0	13
	3	2004	5	0	0	0	0	11
		2005	1	0	0	0	0	13
		2006	2	0	0	0	0	14
		2008	1	1	0	0	0	26
		2009	1	0	0	0	0	13
		2010	1	0	0	0	0	11
Dudley	1	2006	2	0	0	0	0	17
		2007	0	0	0	1	0	46
		2008	1	0	0	0	0	11
		2010	2	0	0	0	0	13

MWI	Flue	Year	No. of days PM_{10} emissions were above the EU-WID daily average particulate limit value*					Concentration of highest PM_{10} emission above EU-WID limit* (mg m^{-3})
			>10 - <20	>=20 - <30	>=30 - <40 (mg m^{-3})	>=40 - <50	>50	
	2	2006	1	1	0	1	1	54
		2007	2	1	0	0	0	21
		2010	1	0	0	0	0	17
Dundee	1	2006	6	0	0	0	0	13
		2007	22	2	0	0	0	25
		2008	2	0	0	0	0	14
	2	2008	1	1	0	1	0	45
		2009	1	1	0	0	0	26
		2010	2	0	0	0	0	16
Edmonton	1	2004	2	0	0	0	0	11
Kirklees	1	2007	3	0	0	0	1	66
Newlincs (Grimsby)	1	2007	1	0	0	0	0	19

MWI	Flue	Year	No. of days PM_{10} emissions were above the EU-WID daily average particulate limit value*					Concentration of highest PM_{10} emission above EU-WID limit* ($mg\ m^{-3}$)
			>10 - <20	>=20 - <30	>=30 - <40 ($mg\ m^{-3}$)	>=40 - <50	>50	
Porthmellon	1	2003	1	0	0	0	0	11
		2006	1	0	0	0	0	13
		2007	3	0	0	0	1	85
		2008	10	4	0	0	0	22
		2009	23	1	1	0	0	39
		2010	19	4	0	2	0	48
SELCHP**	1	2005	2	0	0	0	0	12
Sheffield	1	2006	2	0	0	0	0	19
Stockton-on-Tees	1	2003	41	0	0	0	0	19
		2005	26	0	0	0	0	19
		2008	2	0	0	0	0	19
		2009	0	1	0	1	0	44
		2010	1	0	0	0	0	13

MWI	Flue	Year	No. of days PM_{10} emissions were above the EU-WID daily average particulate limit value*					Concentration of highest PM_{10} emission above EU-WID limit* ($mg\ m^{-3}$)
			>10 - <20	>=20 - <30	>=30 - <40 ($mg\ m^{-3}$)	>=40 - <50	>50	
	2	2003	11	0	0	0	0	15
		2004	5	0	0	0	0	13
		2005	10	0	0	0	0	15
		2006	1	0	1	0	0	35
		2007	2	0	0	0	0	12
		2008	1	0	0	0	1	66
		2009	1	0	0	0	0	11
		2010	2	0	0	0	0	12
Stoke-on-Trent	1	2003	12	0	0	0	0	17
		2007	1	0	0	0	0	15
		2009	1	0	0	0	0	14

MWI	Flue	Year	No. of days PM_{10} emissions were above the EU-WID daily average particulate limit value*					Concentration of highest PM_{10} emission above EU-WID limit* (mg m^{-3})
			>10 - <20	>=20 - <30	>=30 - <40 (mg m^{-3})	>=40 - <50	>50	
	2	2003	7	0	0	0	0	18
		2004	1	0	0	0	0	13
		2006	0	1	0	0	0	25
		2007	1	0	0	0	0	11
		2008	3	0	0	0	0	19
Wolverhampton	1	2003	1	0	0	0	0	18
		2004	2	0	0	0	0	15
		2005	1	0	0	0	0	11
		2006	2	0	0	0	0	19
	2	2003	1	0	0	0	0	11
		2004	1	0	0	0	0	12
		2009	1	0	0	0	0	11

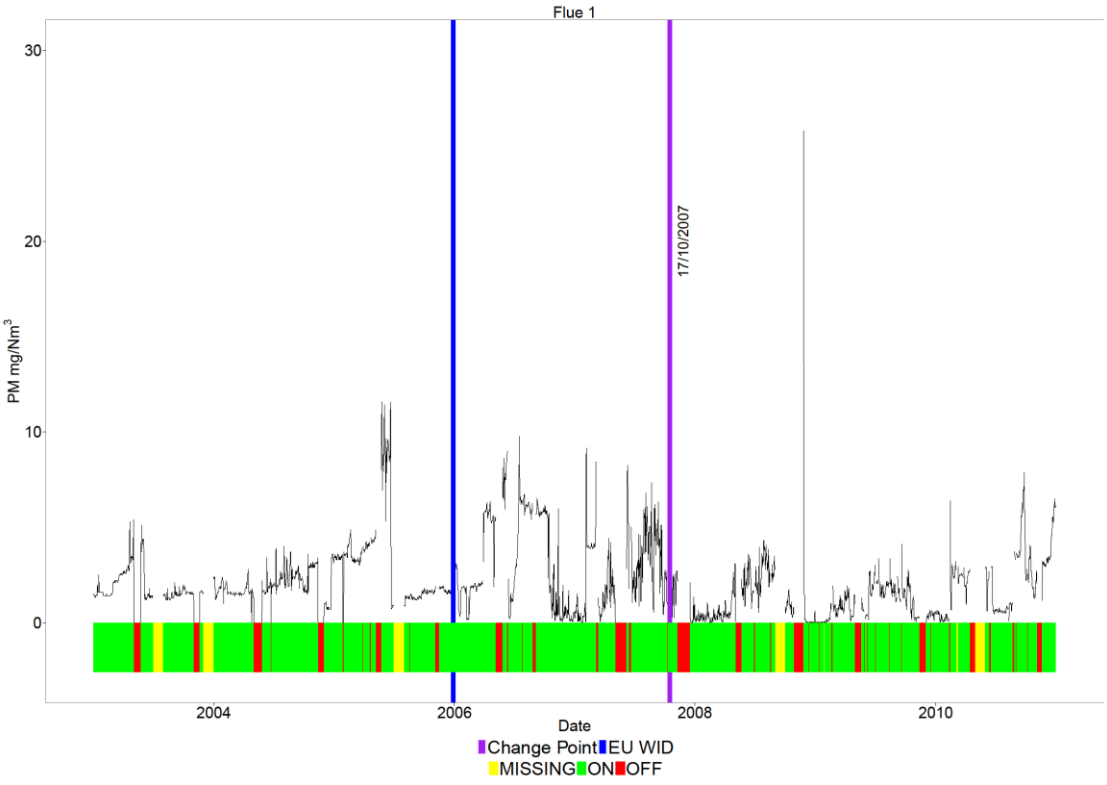
[1]Emissions greater than the EU-WID limit of 10 mg m^{-3} may not represent exceedances under the WID. In the event of temporary abatement failure MWIs are allowed to operate for up to 4 hours at a time (maximum 60 hours per flue per year) at an elevated half-hourly particulate limit value of 150 mg m^{-3} (normally 30 mg m^{-3}). If there are less than 43 half-hourly monitoring results available in a day the daily average can be disregarded.

* Daily average particulate limit value of up to 10 mg m^{-3} per flue

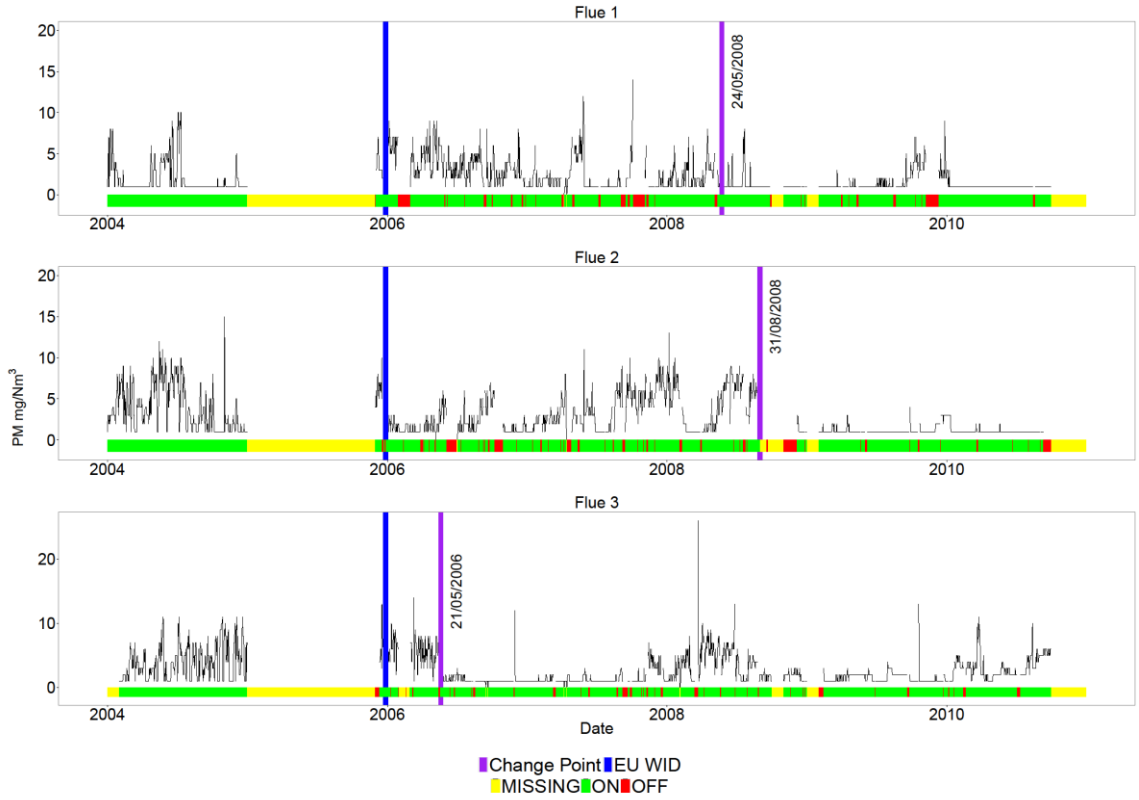
** South East London Combined Heat and Power

K – Change point analysis results

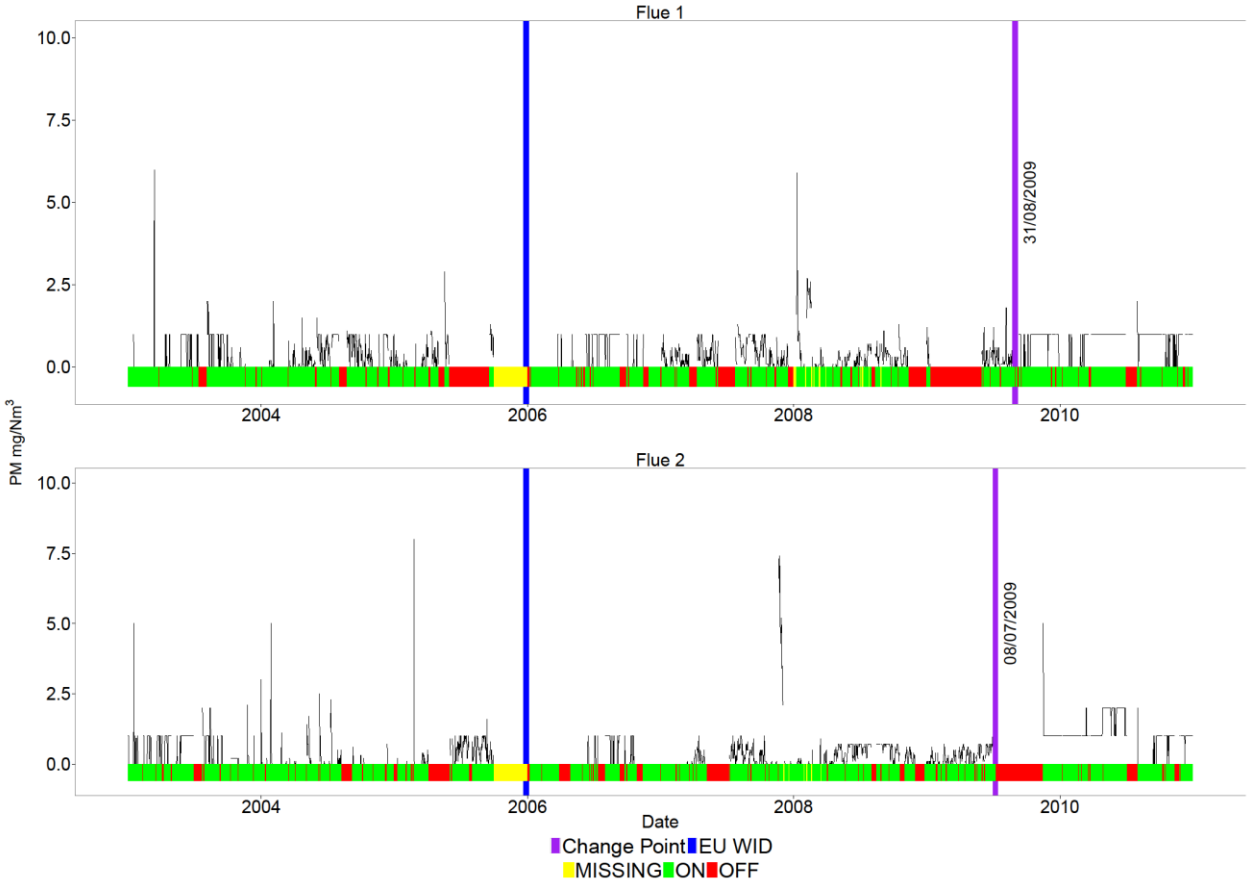
a) Bolton MWI



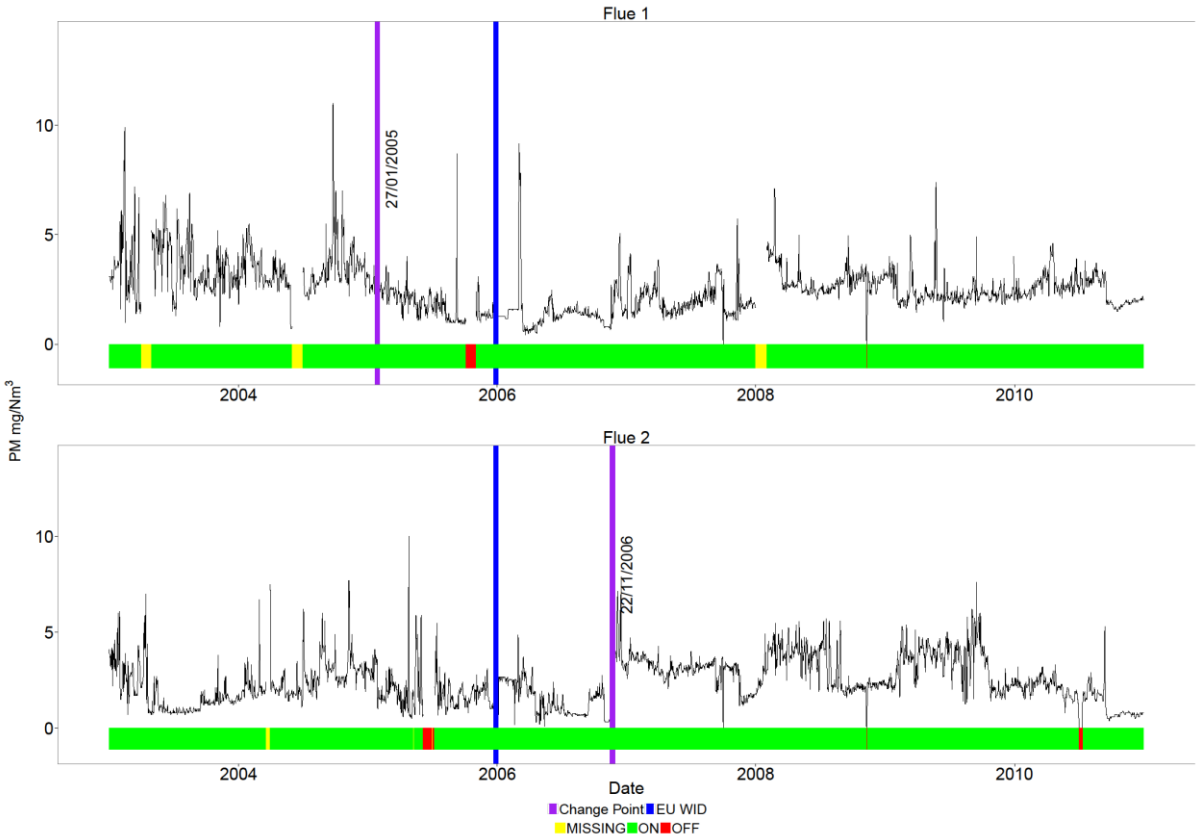
b) Coventry MWI



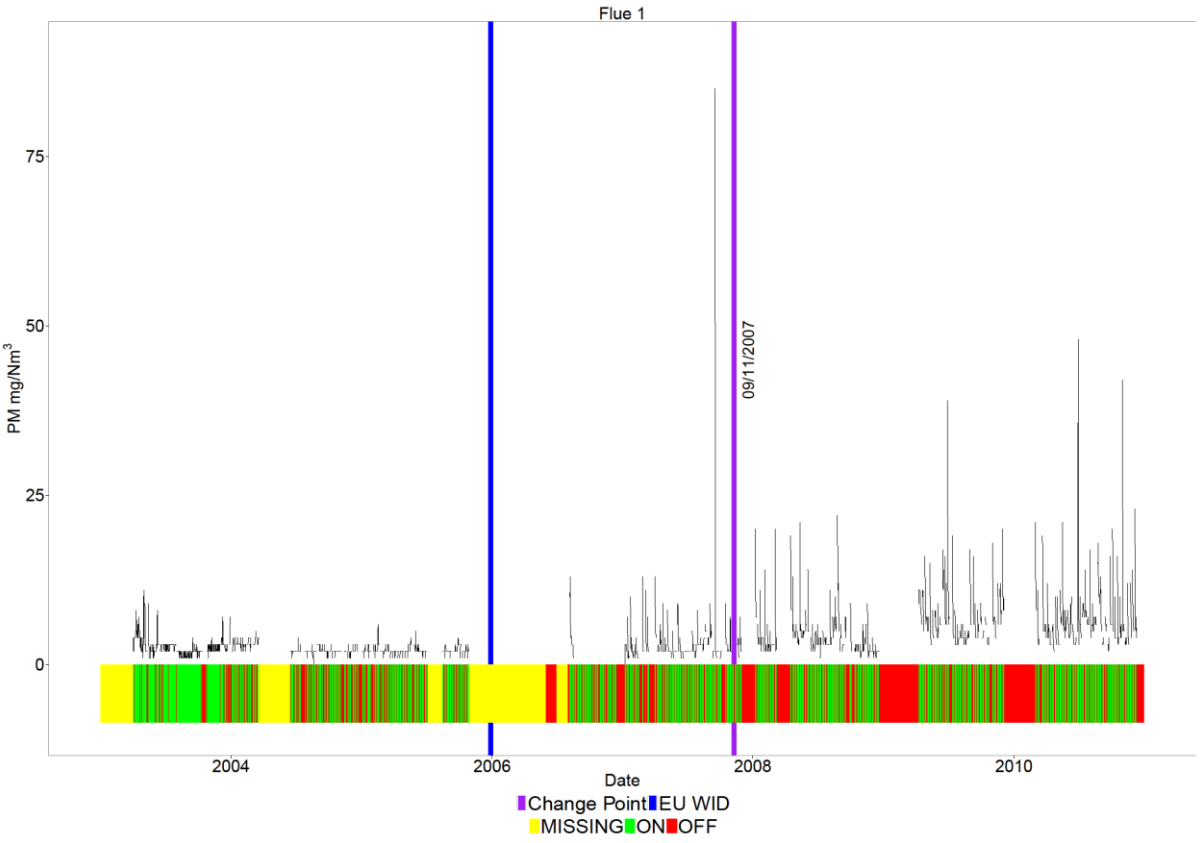
c) Eastcroft MWI



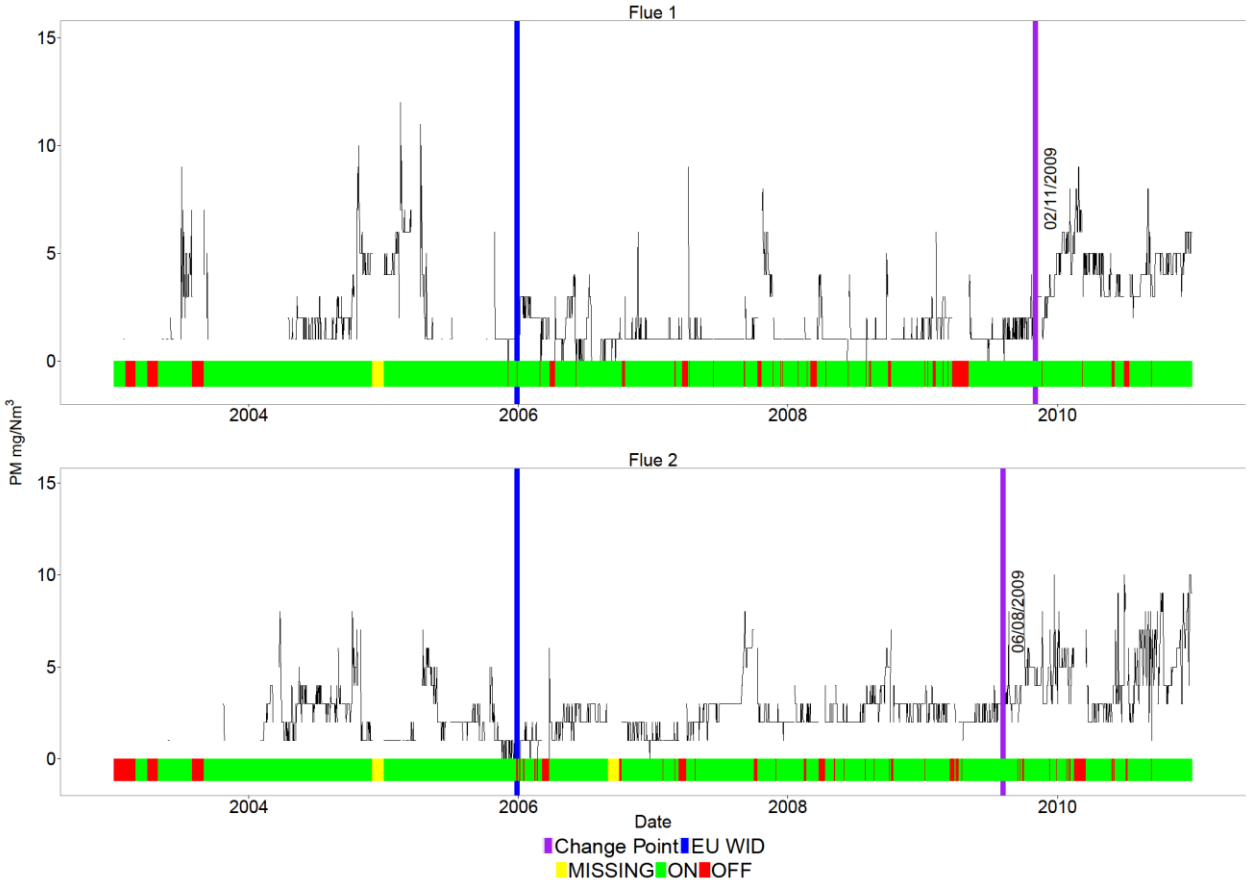
d) Edmonton MWI



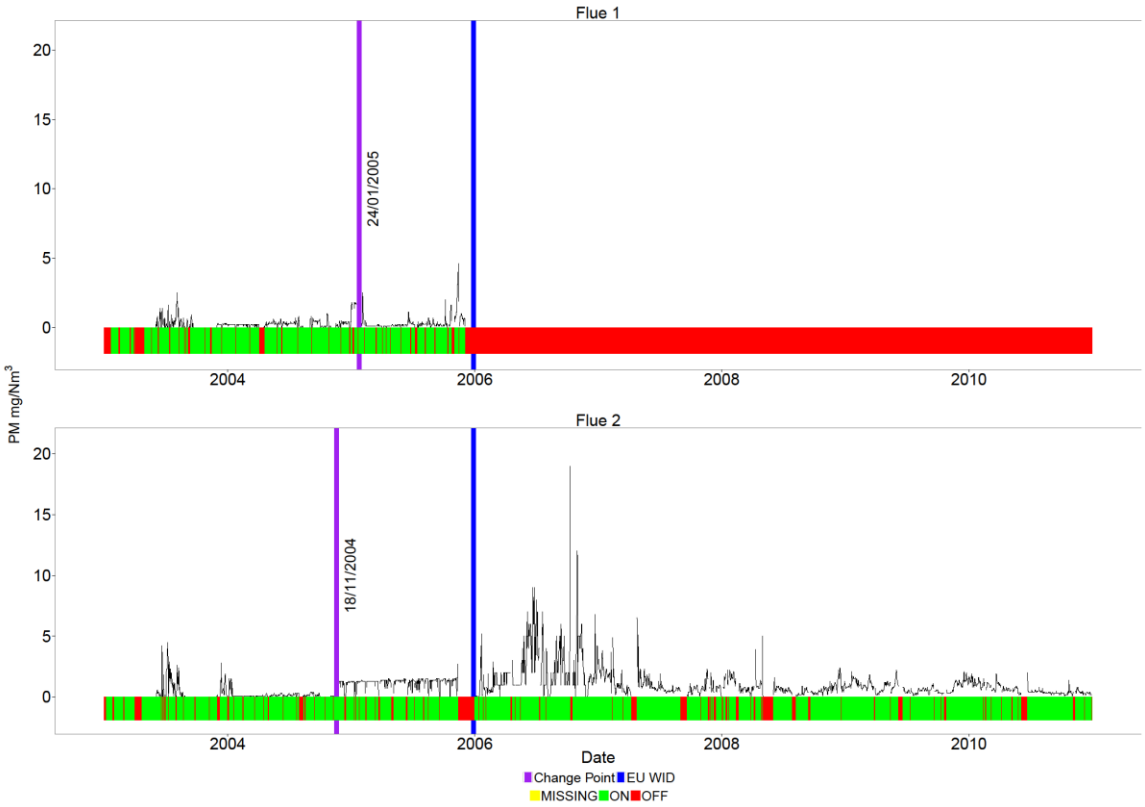
e) Porthmellon MWI



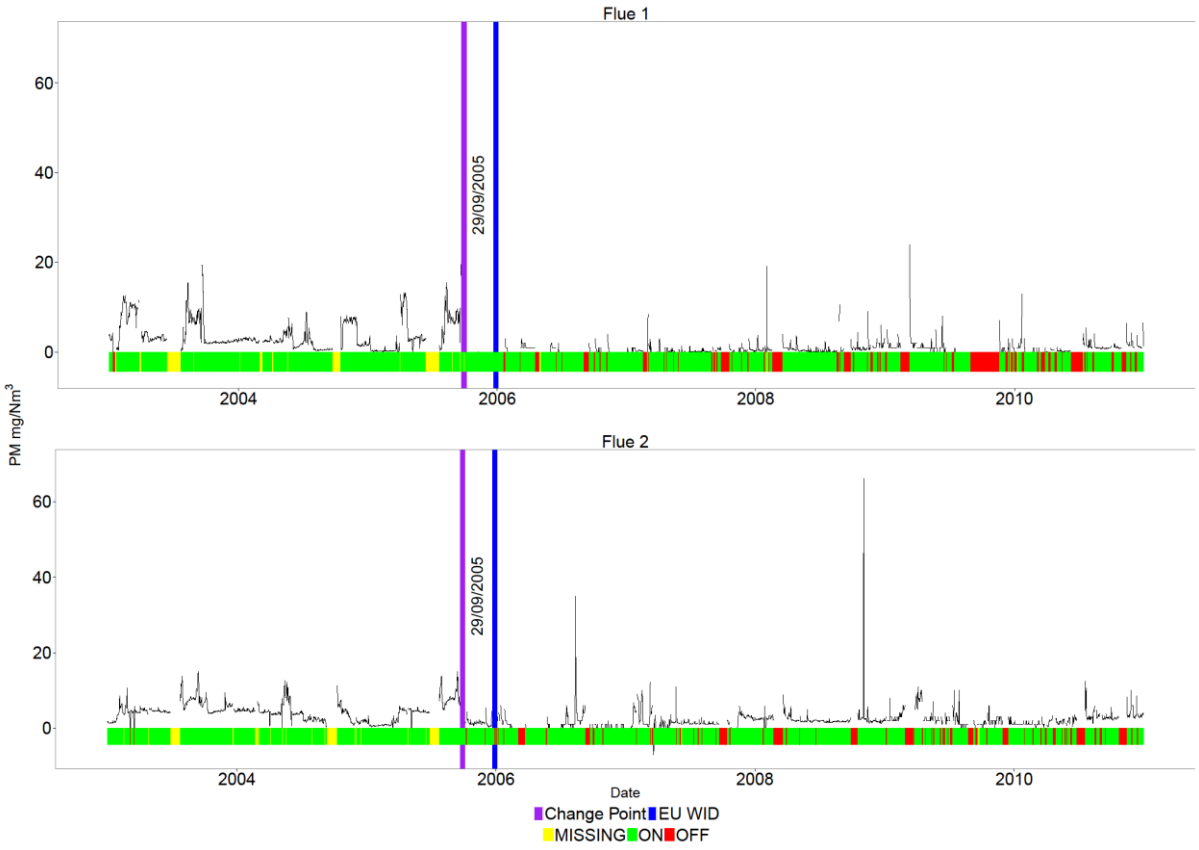
f) SELCHP* MWI



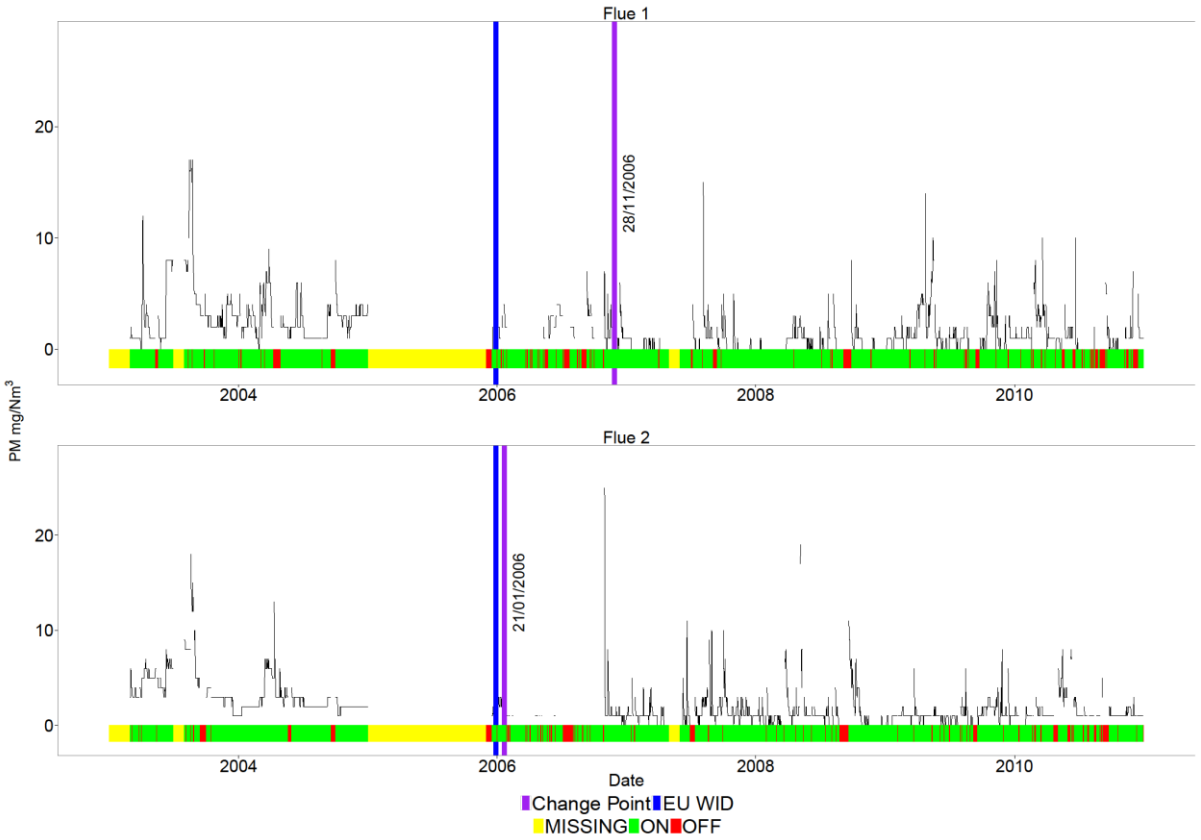
g) Sheffield MWI



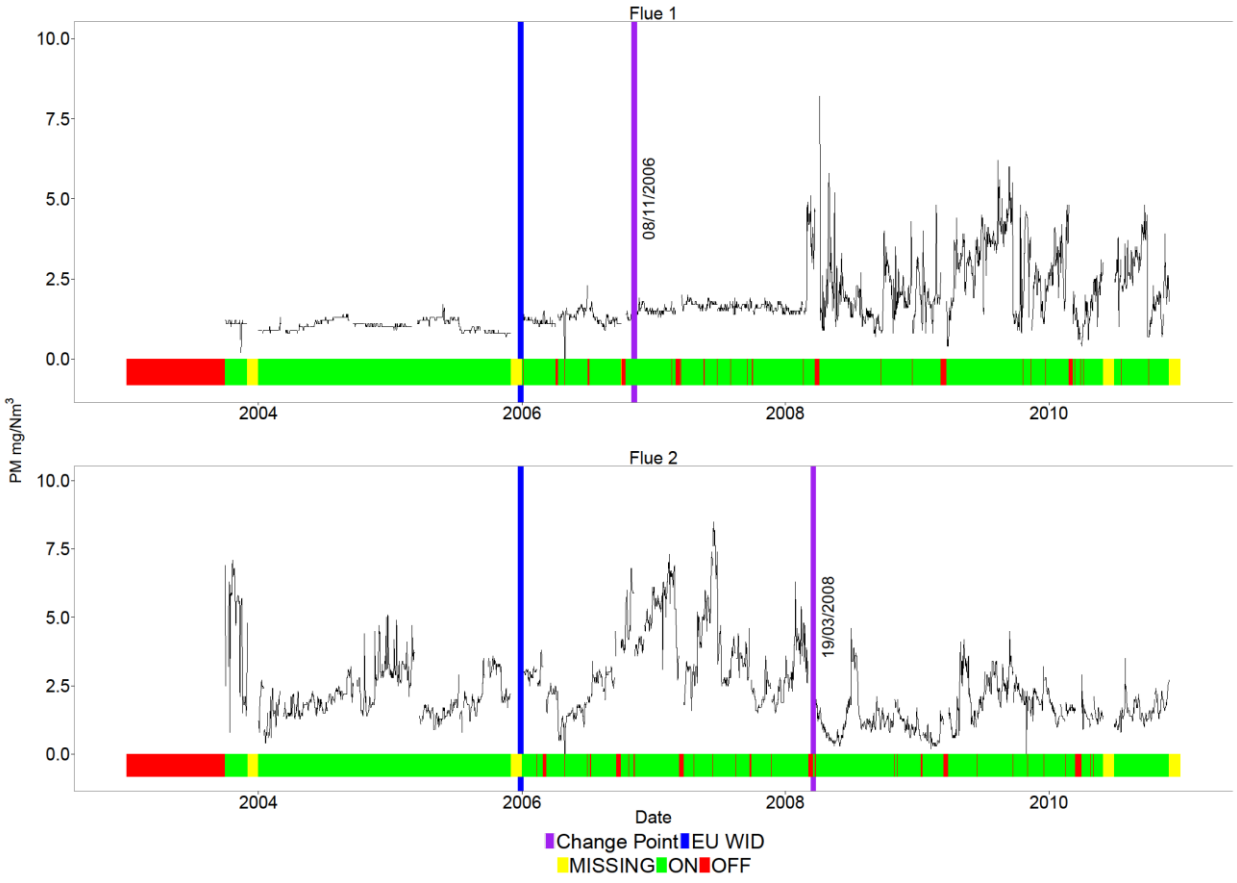
h) Stockton-on-Tees MWI



i) Stoke-on-Trent MWI



j) Tyseley MWI



k) Wolverhampton MWI

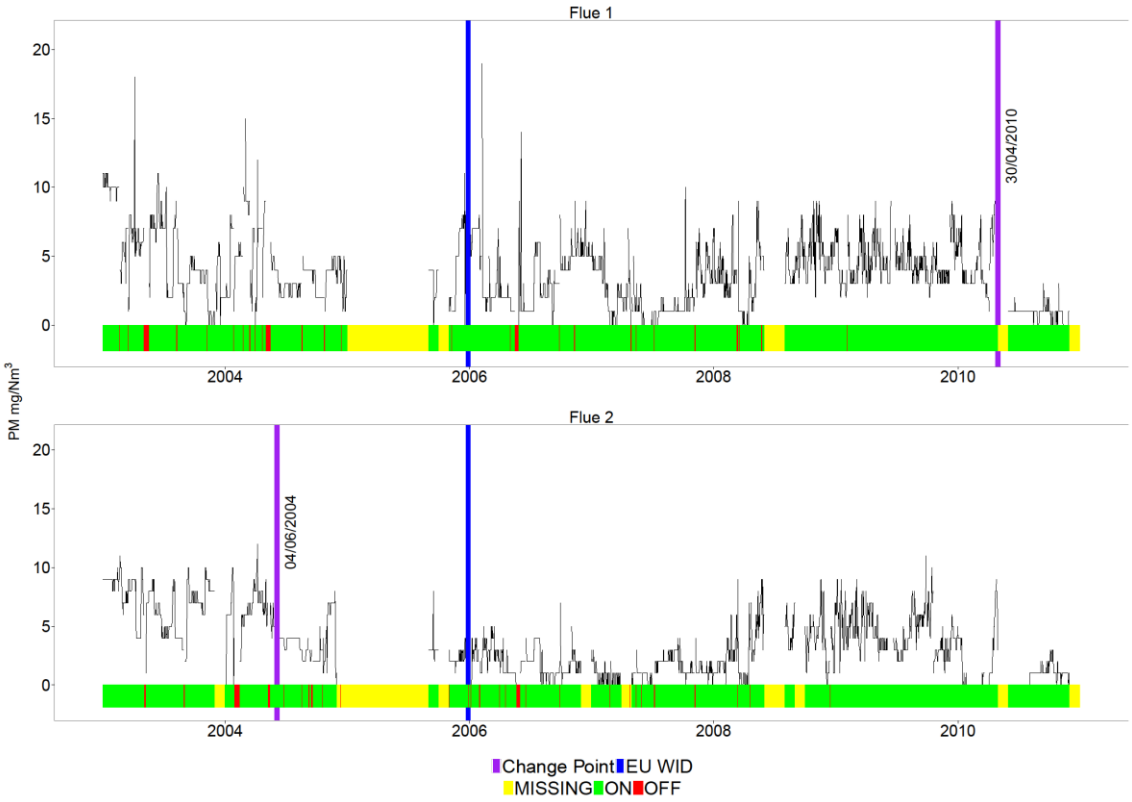


Figure S 4 Monitored PM_{10} data with change points detected using Cramer-von-Mises test for a) Bolton, b) Coventry, c) Eastcroft, d) Edmonton, e) Porthmellon, f)SELCHP, g)Sheffield, h) Stockton-on-Tees, i)Stoke-on-Trent, j) Tyseley, and k) Wolverhampton MWIs. The blue line signifies when the EU-WID was implemented for existing MWIs (28th December 2005), and the purple line signifies the change point. The coloured bar at the bottom of the graph indicates whether the MWI was operational (green), nonoperational (red) or whether data were missing (yellow). Note that SELCHP is an abbreviation of South East London Combined Heat and Power.

*South East London Combined Heat and Power

L - Fingerprinting NO_X to PM_{10} ratios from MWI in-flue concentrations

To evaluate the plausibility of the very low modelled PM_{10} concentrations by ADMS-Urban, we determined diagnostic pollutant ratios for MWI emissions using daily in-flue nitrogen oxides (NO_X) to PM_{10} ratios and compared with those found in ambient air. We tested four MWI sites: Edmonton and South East London Combined Heat and Power (SELCHP) in London; and Tyseley and Wolverhampton in the Midlands. These were selected based on available Air Quality Monitoring Sites (AQMS) measuring both NO_X and PM_{10} within 10 km of an MWI between 2003 and 2010. Daily NO_X to PM_{10} ratios from in-flue tests were calculated and the distribution of the values is summarized in Table S 8.

Table S 8. NOx to PM_{10} ratios (µg NOx/µg PM_{10}) from MWI calculated from daily in-flue measurements

	5th percentile	25th percentile	Median	75th percentile	95th percentile
SELCHP*	26.2	51.3	77.0	153.1	201.2
Edmonton	34.2	51.1	70.1	100.8	228.3
Tyseley	31.4	70.5	108.9	184.4	250.8
Wolverhampton	21.2	31.2	49.6	79.2	158.4

*South East London Combined Heat and Power

To discern MWI emissions from those found in typical urban and traffic locations, representative PM_{10} to NO_X ratios in urban areas and from traffic sources were calculated. Daily urban and traffic increments were computed between 2003 and 2010. Urban increments were calculated by subtracting the rural concentration (as measured in Harwell AQMS) from the urban background measurements (London North Kensington and Leamington AQMSs as representative for the London and Midland atmospheres, respectively). The Harwell AQMS is located 55 miles west of London; and 75 miles south of Leamington. For traffic sources, the urban background concentration (North Kensington) was subtracted from the measurements at London's Marylebone Road kerbside. Data were extracted from the Automatic Urban and Rural Network (AURN)[2] and the London Air Quality Network (LAQN)[3] reported as Tapered Element Oscillating Microbalance (TEOM)*1.3. Representative ratios were calculated using Reduced Major Axis (RMA) regressions and results are summarized in Table S 9.

Table S 9. Representative NOx to PM_{10} ratios (expressed in µgPM_{10}/µgNOx) in urban background locations in London and in the Midlands and from traffic sources.

	PM_{10}/NO_X [95% confidence interval]
London Urban Background	7.90 [7.70, 8.10]
Midlands Urban Background	4.00 [3.90, 4.20]
Traffic sources	12.50 [12.30, 12.70]

NO_X to PM_{10} ratios from MWI in-flue emission concentrations were distinct from those representatives of urban and traffic sources. MWI emissions had median ratios from 21 to 251 µgNO_X/µgPM_{10}, which were greater than traffic sources (12.50 µgNO_X/µgPM_{10}) and urban background locations, in both London and in the Midlands (7.90 and 4.00 µgNO_X/µgPM_{10}, respectively), indicating that MWI emissions are richer in NO_X than traffic and the urban source mixture.

Hourly NO_X and PM_{10} increments were calculated for all AQMS within 10 km of one of the MWIs (Edmonton, SELCHP, Tyseley and Wolverhampton) with data available from 2003 to 2010. Increments were calculated removing the rural concentrations measured at Harwell AQMS to those measured near a MWI. NO_X to PM_{10} ambient ratios were computed from increments. The distribution of ambient ratios when the wind blew from the direction of the MWI (30^o centred at the MWI) were compared with those measured from other wind directions. Figure S 5 illustrates the distribution of ambient NOx to PM_{10} ratios measured at Lewisham – New Cross AQMS when the wind blew from the SELCHP incinerator and from other wind sectors. For both wind sectors, the most abundant measured NO_X to PM_{10} ratios were between those representative of urban and traffic sources with very few occurrences of MWI emissions ratios.

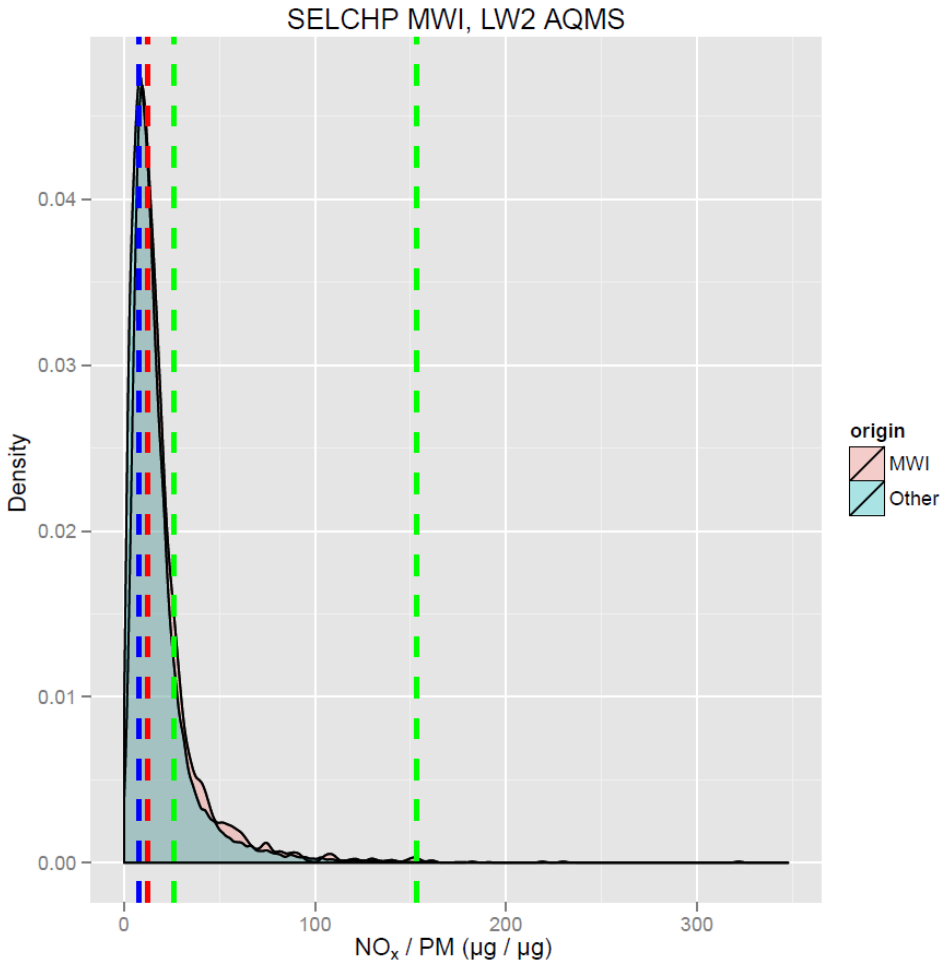


Figure S 5 Distribution of ambient NOx to PM_{10} ratios measured at Lewisham – New Cross Air Quality Monitoring Site (AQMS) when the wind blew from SELCHP MWI and for other wind sectors. Blue, red and green dashed lines indicate the typical NOx to PM_{10} ratios in urban areas, traffic sources and MWI emissions respectively. SELCHP is an abbreviation of South East London Combined Heat and Power

The median ambient NO_X to PM_{10} ratios measured during winds from the MWI was similar to those measured in other sectors and always between the representative rural and traffic values (Table S 10). It can be concluded that MWI emissions are not the main source of NO_X and PM_{10} in nearby urban areas and that their influence on ambient concentrations is small and cannot be disentangled from other sources (e.g. traffic, construction, space heating, etc.).

Table S 10 Median NOx to PM_{10} ambient ratios measured when the wind blew from the closest MWI and for the other wind sectors for the AQMS within 10km of a MWI

MWI	AQMS	Area	Distance (km)	NOx to PM_{10} MWI Sector (25^{th}, 75^{th} percentile)	NOx to PM_{10} Other sectors (25^{th}, 75^{th} percentile)
Edmonton	Haringey Roadside	London Roadside	2.7	8.4(4.7, 14.7)	7.7 (4.4, 13.5)
SELCHP*	London Bloomsbury	London Background	6.9	8.0 (4.9, 14.5)	8.5 (4.9, 14.5)
SELCHP*	London Marylebone Road	London Roadside	8.6	11.7 (8.5, 16.3)	11.2 (8.4, 15.0)
SELCHP*	Lewisham New Cross	London Roadside	1.3	14.9 (9.2, 24.0)	12.8 (7.3, 20.9)
SELCHP*	Greenwich Blackheath	London Roadside	2.8	10.7 (6.9, 16.5)	9.5 (5.6, 15.6)
SELCHP*	Hackney Old Street	London Roadside	8.2	8.2 (5.8, 12.1)	7.9 (5.5, 11.6)
SELCHP*	Greenwich Trafalgar Road	London Roadside	2.8	9.4 (6.0, 15.2)	8.7 (5.0, 14.7)
SELCHP*	Greenwich Westhorne Av.	London Roadside	6.9	5.2 (2.9, 9.3)	6.0 (3.4, 9.8)
SELCHP*	Greenwich Plumstead High St	London Roadside	9.8	8.9 (5.5, 14.5)	6.7 (3.5, 12.1)
SELCHP*	Greenwich Burrage Grove	London Roadside	8.4	12.9 (7.7, 21.6)	10.4 (5.6, 18.1)
SELCHP*	Greenwich Falconwood	London Roadside	9.7	8.7 (5.3, 8.7)	8.2 (4.2, 8.2)
Tyseley	Birmingham Centre	Midlands Background	4.9	6.4 (4.0, 11.5)	4.2 (2.2, 7.8)
Tyseley	Birmingham Tyburn	Midlands Background	5.9	6.2 (3.3, 11.1)	5.5 (2.8, 10.6)

MWI	AQMS	Area	Distance (km)	NOx to PM_{10} MWI Sector (25^{th}, 75^{th} percentile)	NOx to PM_{10} Other sectors (25^{th}, 75^{th} percentile)
Tyseley	Birmingham Tyburn Roadside	Midlands Roadside	5.9	8.2 (5.1, 15.1)	10.4 (6.2, 17.4)
Wolverhampton	Wolverhampton Centre	Midlands Background	1.2	5.6 (3.1, 9.8)	4.7 (2.4, 8.8

*South East London Combined Heat and Power

References

(1) Ashworth, D. C.; Fuller, G. W.; Toledano, M. B.; Font, A.; Elliott, P.; Hansell, A. L.; de Hoogh, K. Comparative assessment of particulate air pollution exposure from municipal solid waste incinerator emissions. *J. Environ. Public Health* **2013**, *2013*, 560342.

(2) DEFRA. UK-AIR, air quality information resource - Defra, UK https://uk-air.defra.gov.uk/ (accessed May 25, 2016).

(3) LAQN. London Air Quality Network http://www.londonair.org.uk/LondonAir/Default.aspx (accessed May 25, 2016).